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WATER QUALITY AND WASTE TREATMENT REQUIREMENTS ON THE UPPER HOLSTON RIVER, KINGSPORT, TENNESSEE, TO CHEROKEE RESERVOIR

Environmental Protection Agency
Athens, Georgia

July 1972

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AND
WASTE TREATMENT REQUIREMENTS
ON THE
UPPER HOLSTON RIVER

Kingsport, Tennessee to Cherokee Reservoir

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Technical Study
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Environmental Protection Agency
Region IV
Surveillance and Analysis Division
Athens, Georgia

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PURPOSE AND AUTHORITY

The report gives information

help

To develop recommendations for waste abatement and water quality management in the upper Holston River system ~~(Figure 1)~~, extensive field investigations were conducted during June and July 1969. Waste discharges and adjacent bodies of water were sampled and analyzed by personnel of the Technical Services Program, Southeast Water Laboratory (now the Surveillance and Analysis Division, Region IV, Environmental Protection Agency) with assistance and cooperation from the Tennessee Valley Authority and the State of Tennessee, Division of Stream Pollution Control.

The water quality standards violated by the pollution sources cited in this report were adopted by the State of Tennessee and accepted by the Federal Government in accordance with the Water Quality Act of 1965 (PL 89-234). In addition, the Holston Army Ammunition Plant (HAAP) is administered by the U. S. Corps of Engineers and is, therefore, subject to Federal regulation under Executive Order No. 11507, which provides for treatment of wastes from Federal facilities.

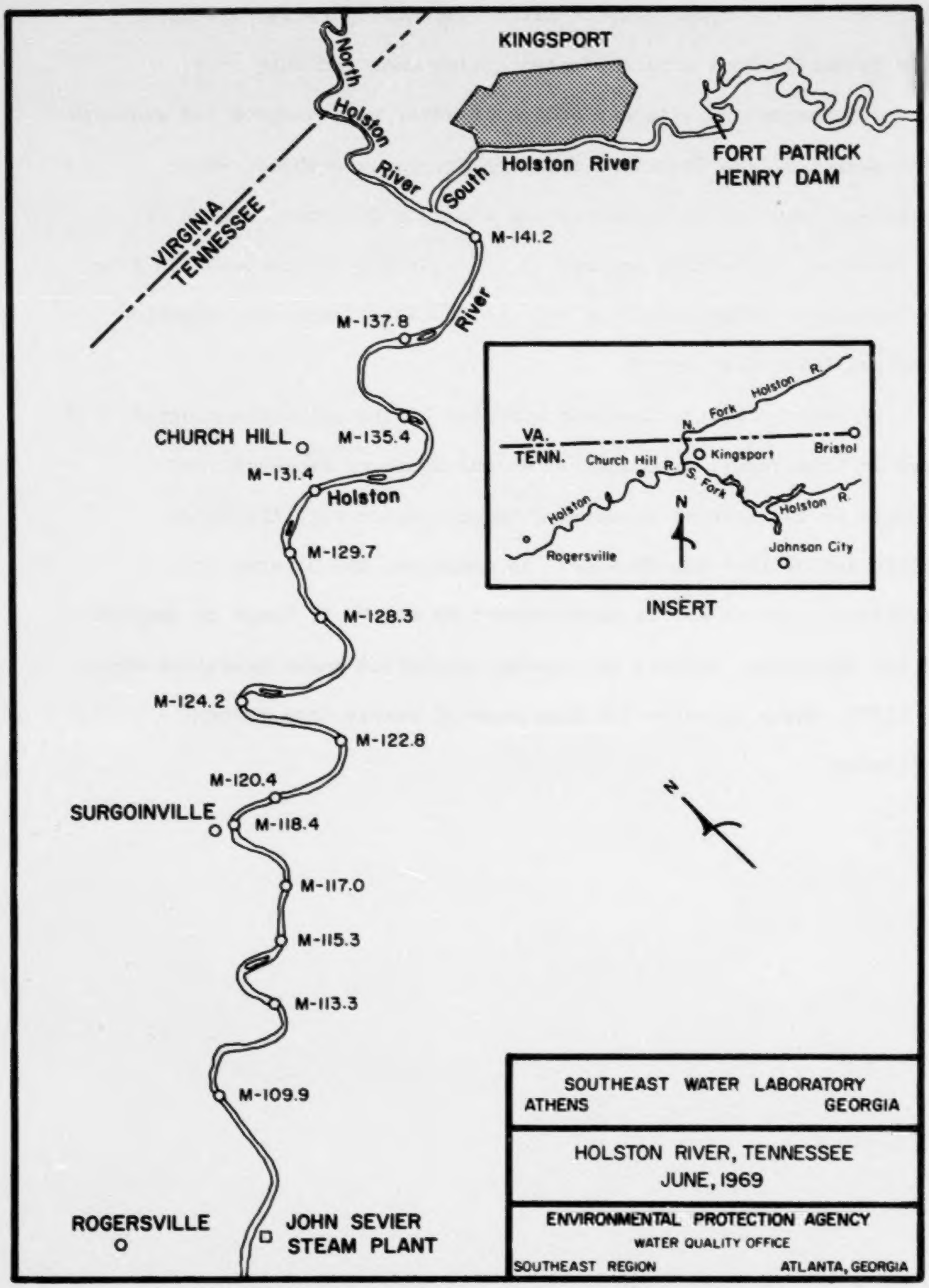

KINGSPORT
North Holston River
South
Holston River
FORT PATRICK HENRY DAM
VIRGINIA
TENNESSEE
M-141.2
River
M-137.8
CHURCH HILL
M-135.4
M-131.4
Holston
M-129.7
M-128.3
M-124.2
M-122.8
M-120.4
SURGOINVILLE
M-118.4
M-117.0
M-115.3
M-113.3
M-109.9
ROGERSVILLE
JOHN SEVIER STEAM PLANT
VA.
TENN.
N. Fork Holston R.
Kingsport
Bristol
Church Hill
R.
S. Fork
Holston R.
Holston
Rogersville
Johnson City
N
INSERT
N
SOUTHEAST WATER LABORATORY
ATHENS GEORGIA
HOLSTON RIVER, TENNESSEE
JUNE, 1969
ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
SOUTHEAST REGION ATLANTA, GEORGIA

FIGURE 1 Map Showing the River Sampling Station Locations

FINDINGS

1. At the time of this survey, wastes with approximately 137,500 pounds per day of five day biochemical oxygen demand (BOD_5) were discharged into the Holston River, and its tributary, the South Fork Holston River, in the vicinity of Kingsport, Tennessee. The total discharge of these six sources (Table I) is equal to a population of 810,000, compared to the 1970 population of the Kingsport area of approximately 45,000.

2. Sources of total Kjeldahl nitrogen (TKN -- organic nitrogen and ammonia expressed as nitrogen) are also shown in Table I. The ultimate oxygen demand from nitrification of these nitrogenous components in the Kingsport area was 84,000 pounds (in addition to BOD_5).

3. Extensive sludge beds covered an estimated 25% of the total bottom area of the Holston River between the confluence of the North and South Forks of the Holston Rivers and the headwaters of Cherokee Reservoir. Average rates of benthic oxygen consumption, measured at 26°C, ranged from 7,300 lbs/day for the 3.3 mile reach directly below the confluence, to 3,860 lbs/day for the 3.2 mile reach below Churchill Bridge. The total benthic oxygen consumption for the 22.8 miles of the Holston River analyzed was in excess of 31,200 lbs/day.

TABLE 1

SOURCES OF WASTE COMPONENTS IN THE AREA OF KINGSPORT, TENNESSEE

Waste Source	BOD_5 lbs/day	% of Total BOD_5
Tennessee Eastman Corporation	69,300	50.4
Holston Army Ammunition Plant		
Area A	23,480	17.1
Area B	32,200	23.4
Mead Paper Company	11,700	8.5
Holliston Mills	320	0.2
Kingsport Municipal Sewage Treatment Plant	500	0.3
	137,500	100.0

Waste Source	TKN lbs/day	% of Total TKN
Tennessee Eastman Corporation	16,120	83
Holston Army Ammunition Plant		
Areas A & B	3,055	16
Remaining Sources	250	1
	19,425	100

4. An estimated 170 tons of attached aquatic weeds (primarily Potamogeton pectinates) were found to cover the river bottom almost completely in a dense luxurious growth throughout the length of the 22.8 river mile study area. The net effect of these weeds on the dissolved oxygen balance in the river, when viewed over a full 24-hour period, was to add oxygen to the system. Net oxygen increases resulting from the primary productivity of these weeds ranged from 23,000 lbs/day in the reach directly below the confluence to 4,200 lbs/day in the 2.2 mile reach directly below the main outfall of Holston Army Ammunition Plant, Area B. Although the net daily effect of the plants was beneficial to the dissolved oxygen resources of the river, cyclical variation in the rate of oxygen production and consumption produced excessive variation of dissolved oxygen levels. During the hours of darkness, oxygen concentrations in the water were observed to fall at a rate approaching 0.5 mg/l per hour, or approximately 50,000 lbs/day. Ranges in dissolved oxygen levels of over 6.0 mg/l were observed at some sampling locations as a result of these diurnal fluctuations. Near total depletion of oxygen for a distance of over five river miles of the river system resulted.

5. Temperature increased in the South Fork and the mainstem of the Holston River as a result of cooling water discharges by the Tennessee Eastman Corporation and Areas A and B of the Holston Army Ammunition Plant. Temperatures of the South Fork were increased from an average of 15.5°C to over an average of 26.9°C

in the 4.4 mile reach into which the Tennessee Eastman Corporation and Area A of the HAAP discharge cooling water. This amounts to an increase of 11.4°C or 20.5°F above water temperatures upstream of the plants. The water temperature of the Holston River below Area B of the Ammunition Plant was increased an additional 1.3°C or 2.3°F during the July 1969 study by cooling water discharges from the plant. Temperature standards recently agreed upon by the EPA and the State of Tennessee restrict temperature increases to 3°C.

6. At Fort Patrick Henry Reservoir, the Tennessee Valley Authority operates a hydroelectric power installation on the South Fork, about six miles upstream from the City of Kingsport. This plant has a marked effect upon the hydrological regimen of both the South Fork and the Holston River, especially during off peak power generating periods when water releases from the reservoir may be reduced to a daily average of 750 cfs (3000 cfs for one hour, off for three hours). When this coincides with low flows in the North Fork, total flows in the Holston River may be reduced to about 800 cfs. Releases during these periods are made primarily from the hypolymnion of the reservoir, resulting in dissolved oxygen concentrations depressed well below the saturation level. The mean dissolved oxygen level below the dam over a diurnal cycle was 4.9 mg/l.

CONCLUSIONS

1. Pollution abatement schedules and limits for the Kingsport area set by the Tennessee Division of Water Quality Control and by appropriate U. S. Environmental Protection Agency divisions should be implemented without delay.

2. A minimum of 6.0 mg/l dissolved oxygen (as required by the Tennessee Water Quality Standards for trout streams) should be maintained at all times in the releases of water from Fort Patrick Henry Dam.

3. Based on the assumptions made for the mathematical model in Appendix F and in "Rationale" (next section), the total pollutional loads discharged into the study area should be limited to a maximum of 14,040 lbs/day BOD_5 and 1940 lbs/day TKN. The abatement measures currently required of waste sources in the Kingsport area by the Tennessee Division of Water Quality Control will produce a significant improvement in water quality. However, all dischargers should be put on notice that additional treatment requirements over and above those now in present implementation plans may be imposed where a comprehensive water quality management plan for the Holston Basin is developed.

The calculated limits are the equivalent of an estimated 92 percent reduction of untreated BOD_5 from all waste sources and 92 percent reduction of the untreated TKN from the two major sources in the area (Tennessee Eastman Company and the Holston Army Ammunition Plant, Area B). These percentage removal figures could be reduced to 89 percent if, in fact, TVA can maintain 6 mg/l dissolved oxygen downstream from Fort Patrick Henry Dam (calculations in this report are based on 5 mg/l DO releases).

4. Kjeldahl nitrogen must be removed and not merely converted to nitrates and discharged. Otherwise, the already prolific aquatic weed population will rapidly increase since nitrates are readily assimilated by green plants.

5. No new waste discharges or increase in present waste discharges should be allowed in the reach between Fort Patrick Henry Dam on the South Fork Holston River and Church Hill (River Mile (RM) 131.5) on the Holston River which will further degrade water quality.

6. The present minimum flow release of 750 cubic feet per second as equalized by the Tennessee Eastman dam should be maintained. Flow should not be reduced even if TVA must absorb the loss of power potential.

7. Studies should be conducted to estimate the costs and difficulties of installing in Fort Patrick Henry Dam a 750 cfs turbine designed to run continuously if required. This equipment would be used to eliminate the present practice of discharging 3000 cfs every fourth hour for equalization at the Tennessee Eastman dam.

8. A study should be initiated to devise the most feasible and effective method for limiting the growth of aquatic weeds in the upper reaches of the Holston River. Techniques to control both long-term effects (e.g. periodic harvesting, phosphorus and/or nitrogen removal from waste sources, etc.) and short-term effects (e.g. flow augmentation, in-stream reaeration, temperature control, etc.) should be included in such a study.

9. Cooling techniques must be adopted by the Tennessee Eastman Corporation and the Area A plant of the Holston Army Ammunition Plant to reduce the temperature increase in the South Fork Holston River. The total temperature increase between South Fork river miles 5.6 and 1.2 should not exceed 6°C (assumed 3°C increase for each outfall) on a daily average (as required by Tennessee Water Quality Standards).

10. A centralized municipal-industrial waste collection and treatment system should be seriously studied as a means of achieving the recommendations of this study. Metropolitan plans addressed to this alternative may be completed under procedures defined in 18CFR 601, paragraphs 31-33, and Environmental Protection Agency *Guidelines: Water Quality Management Planning*, January 1971.

RATIONALE

Calculated dissolved oxygen (DO) profiles are superimposed in Figure 2 on the dissolved oxygen minimum established by the Tennessee Stream Standards. These projections ignore the effect of photosynthesis and respiration and are based on the observed 1969 discharges. A reduction of 90% of the 1969 discharges is needed to allow recovery to the 5 mg/l minimum at the Church Hill Bridge, even though 85% waste reductions (both BOD_5 and TKN) will not depress the DO profile below the 3 mg/l minimum between the confluence (RM 142.2) and the Church Hill Bridge (RM 13.5) when the effects of photosynthetic respiration are ignored. (Ninety percent reduction of the 1969 discharges is equivalent to 92% reduction of the raw waste loads as estimated from 1969 discharge data.) Since nearly 99% of the TKN is discharged from two sources, Tennessee Eastman and Area B of the Holston Army Ammunition Plant, TKN reduction is allocated between these two sources only.

Table 2 shows the distribution of the oxygen demand among the various reaches of the river considered in this study. A simple "trade-off" from treatment of nitrogenous components to carbonaceous components of waste discharges will not be effective because in the most critical reach (SFHRM 1.2 - HRM 131.5), the nitrogenous oxygen demand (based upon TKN) represents nearly 25% of the total oxygen consumed.

Figure 3 correlates the effects of varying DO levels in Fort Patrick Henry Dam discharges with the percent waste treatment needed

TABLE 2

DISTRIBUTION OF RIVER OXYGEN DEMAND

HOLSTON RIVER

River Mile	% of Total Demand	Distribution of Demand (% of Total)		
		Percent Carbonaceous (B.O.D.)	Percent Nitrogenous	Percent Bottom
South Fork				
1.2	8.5	8.5	--	--
Confluence				
Holston River				
Confluence				
137.9	34.1	16.3	14.1	3.7
135.4	19.8	13.9	3.8	2.1
131.5	20.2	16.4	2.2	1.6
128.3	3.8	--	2.5	1.3
124.3	6.0	--	3.6	2.4
118.4	7.6	--	3.7	3.9
TOTAL	100.0	55.1	29.9	15.0

NOTE: T = 30°C

Q = 800 cfs

D.O. from Fort Patrick Henry Dam = 5 mg/l

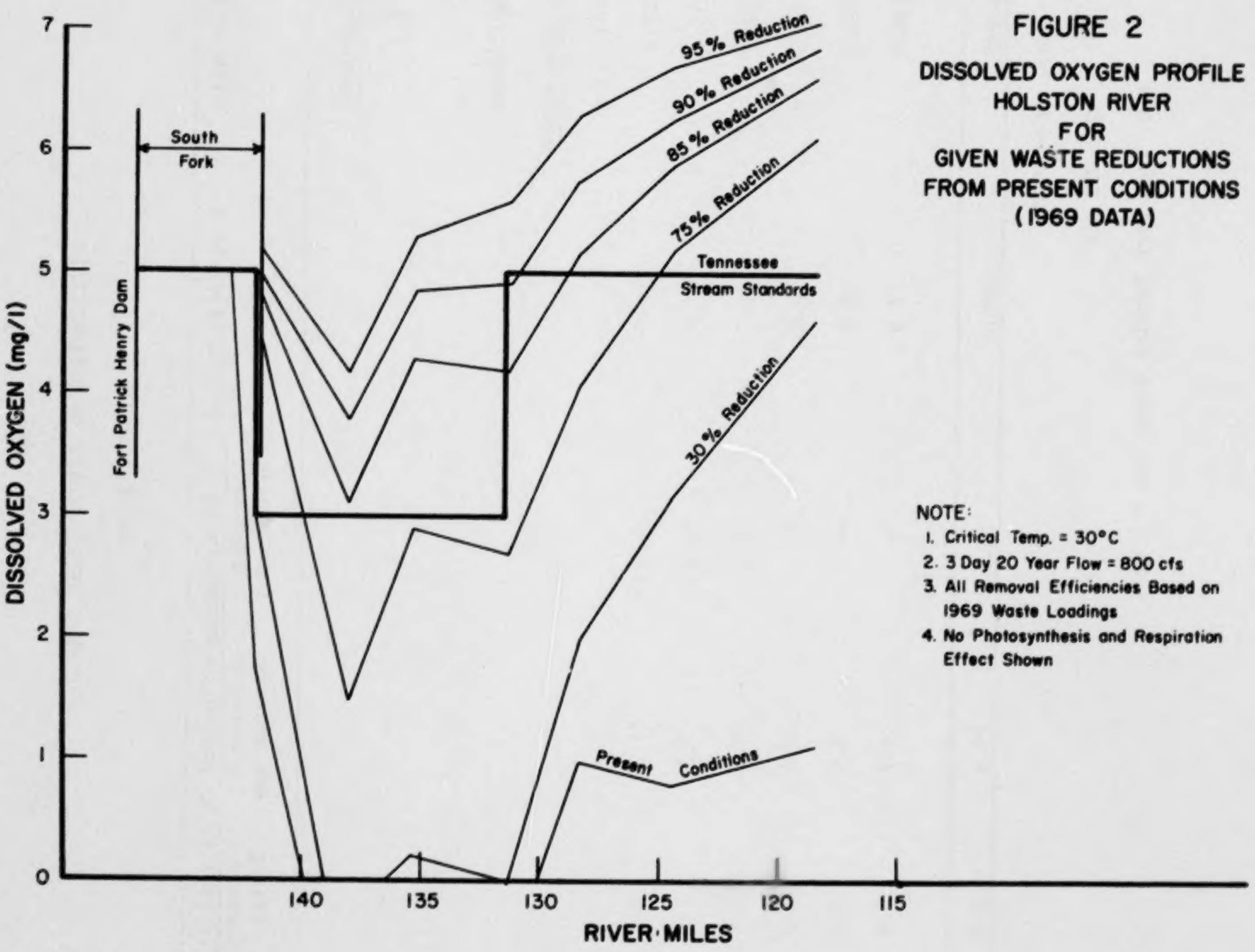


FIGURE 2

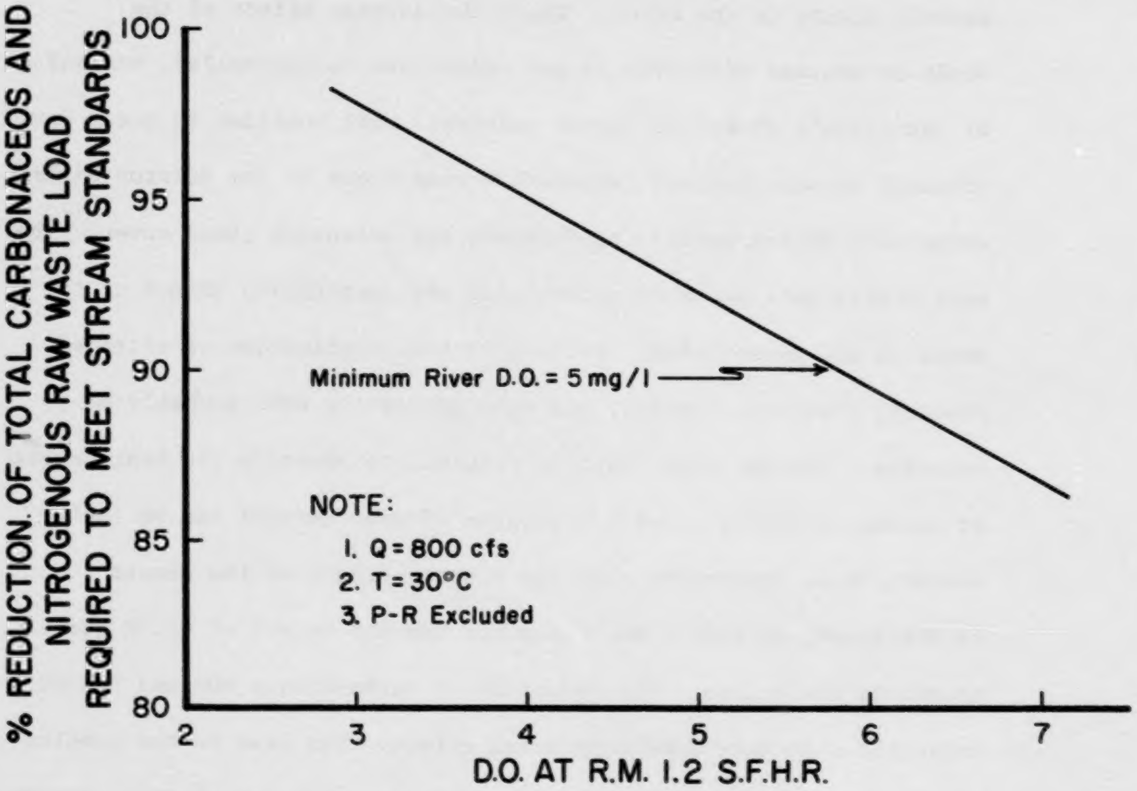
DISSOLVED OXYGEN PROFILE
HOLSTON RIVER
FOR
GIVEN WASTE REDUCTIONS
FROM PRESENT CONDITIONS
(1969 DATA)

NOTE:

1. Critical Temp. = 30°C
2. 3 Day 20 Year Flow = 800 cfs
3. All Removal Efficiencies Based on 1969 Waste Loadings
4. No Photosynthesis and Respiration Effect Shown

FIGURE 3

NECESSARY WASTE REMOVALS
VS.
D.O. FROM FORT PATRICK HENRY DAM



to maintain 5 mg/l DO at the recovery point (RM 131.5) of the DO stream standard. Changing the DO discharged from the dam by 1 mg/l is equivalent to approximately 3 percent waste removal from all the major point sources. Any future expansion in the area would require a guarantee of increased DO from Fort Patrick Henry Dam and/or advanced waste treatment from both the new waste discharges and from existing discharges.

Even the recommended 92% reduction of BOD_5 and TKN will not rectify the detrimental influence of respiration of the attached aquatic plants in the river. Until the adverse affect of the weeds on minimum dissolved oxygen values can be controlled, violations of the state's dissolved oxygen standards will continue to occur during critical stream flow and temperature conditions in the Holston River especially during periods of darkness and extensive cloud cover. The most practicable means of controlling the respiration effect of the weeds is not established. Ultimately some combination of nitrogen removal, phosphate removal, and weed harvesting will probably be selected. Further study will be required to identify the best course of action available. Until a program of weed control can be implemented, it is imperative that the adverse effect of the plants be minimized, to reduce the frequency and the extent of water quality standards violations. The reduction of carbonaceous BOD and TKN is anticipated to have some beneficial effect. The crux to the problem is to remove TKN from the system, and not merely convert it to another form, such as NO_3. Nitrates would probably stimulate vegetative growth in the upper reaches of the river, in the region most critically depressed.

Short-term water quality management techniques should also be considered such as: (1) flow augmentation from the Fort Patrick Henry Reservoir; (2) in-stream reaeration; and (3) temperature control of heated discharges.

STUDY AREA

A. General Description

The Holston River basin is located in southwestern Virginia and northeast Tennessee (Figure 1). The Holston River itself is formed by the confluence of the South Fork and the North Fork at Kingsport, Tennessee. The area of consideration for this report is the North Fork in Tennessee, the South Fork from Fort Patrick Henry Dam to the confluence with the North Fork, and the Holston River from the confluence to the headwaters of Cherokee Reservoir.

The Kingsport area is heavily industrialized with most wastes being discharged to the South Fork. The Holston Army Ammunition Plant (HAAP) occupies the north bank of the Holston River from the confluence (river mile 142.2) to approximately river mile (RM) 137. Downstream of this point industrial use is limited partially due to increased hardness and chlorides discharged upstream on the North Fork by Olin Corporation of Saltville, Virginia. The Holston River is relatively inaccessible to boating in the upper reaches and is not presently suitable for navigation. The John Sevier steam plant of the Tennessee Valley Authority uses the Holston River as a source of cooling water at RM 106.5 just upstream of Cherokee Reservoir.

The largest population center in the area under consideration is Kingsport, Tennessee with 31,900 people and Kingsport North with 13,100. Other municipalities along the Holston River include Church Hill with 2,800 and Rogersville with 4,000. Gate City, Virginia located just north of the state line on the North Fork has a population of 1,900. (All are 1970 Census Report figures rounded to the nearest 100.)

B. Water Quality Standards

Table 3 shows the Tennessee Water Quality Standards that have been applied to the study area. The streams carry several classifications, but all include "Fish and Aquatic Life." This classification carries a minimum dissolved oxygen of 5 mg/l designation except designated reaches below waste outfalls which carry a 3 mg/l minimum. The detailed Water Quality Criteria are shown in Appendix A.

C. Hydrology

The Tennessee Water Quality Criteria are applied on the basis of two definitions of minimum flow: (1) unregulated streams -- 3-day minimum, 20-year recurrence interval, and (2) regulated streams — instantaneous minimum flow.

The low three day flow that can be expected once in 20 years is 46 cfs in the North Fork at Gate City, Virginia (records through 1967). The instantaneous low flow in the South Fork below Fort Patrick Henry Dam is zero (South Fork river mile 8.2).

The Tennessee Valley Authority is required to release 450 cfs from Fort Patrick Henry Dam as an absolute minimum daily low flow. However, the Tennesse Eastman Company of Kingsport requires a minimum daily flow of 750 cfs for process and cooling water. By arrangement with the Tennessee Valley Authority, Tennessee Eastman purchases the additional water for its needs. Minimum releases are made primarily on weekends on a four hour peaking cycle, with no flow for three hours out of four, such that a minimum daily flow of 750 cfs is maintained. Tennessee Eastman maintains a small stilling reservoir in the South Fork below Fort Patrick Henry Dam to partially smooth these peak flows.

TABLE 3
TENNESSEE WATER QUALITY STANDARDS AS APPLIED TO THE STUDY AREA

River Basin Holston River

Stream	Mileage	Description	Use Classification	Base Parameters
Holston River	0.0-131.5	From River Mouth to Bridge at Churchill	Domestic Raw Water, Industrial Water Supply Fish and Aquatic Life, Recreation, Irrigation, Livestock Watering and Wildlife	Dissolved Oxygen 5.0 mg/l, pH 6.5-8.5, Coliform Group 10,000 per 100 ml, Fecal Coliform 1,000 per 100 ml, Temperature* 87°F maximum temperature increase. Total Dissolved Solids 500 mg/l.
	131.5-142	From the Bridge at Churchill to the Origin	Industrial Water Supply, Fish and Aquatic Life, Irrigation, Livestock Watering and Wildlife	Dissolved Oxygen 3.0 mg/l, Total Dissolved Solids 500 mg/l, pH 6.5-8.5
South Fork Holston River	4.5-62.8	Tennessee Eastman Dam to Virginia-Tennessee state line	Domestic Raw Water Supply, Industrial Water Supply, Fish and Aquatic Life, Recreation, Irrigation, Livestock Watering and Wildlife	Dissolved Oxygen 5.0 mg/l (Except Trout Waters 6.0 mg/l) pH 6.5-8.5, Total Dissolved Solids 500 mg/l, Temperature* 87°F maximum temperature increase 5°F. (Except Trout Waters 68°F.) Fecal Coliform 1,000 per 100 ml, Coliform Group 10,000 per 100 ml.
		(Note: Sluice Way Carries Same Use Classification)		
	0.0-4.5	River mouth to Tennessee Eastman Dam	Industrial Water Supply, Fish and Aquatic Life	Dissolved Oxygen 3.0 mg/l, Temperature 87°F. maximum temperature increase 5°F, Total Dissolved Solids 500 mg/l, pH 6.5-8.5 *
North Fork Holston River	0.0-5.2	River mouth to the Virginia-Tennessee state line	Fish and Aquatic Life, Recreation, Livestock Watering and Wildlife	Dissolved Oxygen 5.0 mg/l, Temperature 87°F maximum * temperature increase 5°F., pH 6.5-8.5, Fecal Coliform 1,000 per 100 ml.
Watauga River	0.0-18.0	River mouth to upstream end of Lacy Island	Domestic Raw Water Supply, Industrial Water Supply, Fish and Aquatic Life, Recreation, Irrigation, Livestock Watering and Wildlife	Dissolved Oxygen 5.0mg/l(Except Trout Waters 6.0 mg/l), pH 6.5-8.5, Temperature 87°F maximum* temperature increase 5°F. (Trout Waters 68°F), Coliform Group 10,000 per 100ml, Total Dissolved Solids 500 mg/l. Fecal Coliform 1,000 per 100 ml.

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* Temperature criteria modified (Appendix A)
Maximum rise: 3°C; Absolute maximum: 30.5°C except for trout; Maximum rate: 2°C/hr

Assuming that TVA will adjust its releases to provide a 750 cfs instantaneous low flow in the South Fork, the critical three-day, twenty-year low flow for the Holston River is the summation of 46 cfs for the North Fork and 750 cfs for the South Fork. Subsequent calculations are based on 800 cfs.

WASTE DISCHARGES

The South Fork of the Holston River downstream of Fort Patrick Henry Dam, and the Holston River downstream of the confluence of the North and South Fork, are grossly polluted by five major waste dischargers in and around the Kingsport, Tennessee, area:

Tennessee Eastman Corportion
Holston Army Ammunition Plant
Mead Paper Company
City of Kingsport sewage treatment plant
Holliston Mills (~12 miles downstream of Kingsport)

The Holston Army Ammunition Plant is operated for the U. S. Government by the Holston Defense Corporation, a subsidiary of Tennessee Eastman.

The raw waste load from those sources totals 170,150 pounds per day of BOD_5 (estimate from 1960 and 1969 data) and 19,500 pounds per day of TKN (1969 data). This nitrogen load is equivalent to an oxygen demand of 84,000 pounds per day, based on an empirical conversion factor of 4.33 pounds of oxygen per pound of ammonia[1/] (TKN in this case). Waste treatment recommendations are based on these preceding data; while stream DO calculations are based on the 1969 observed discharges (some partially treated) totaling 140,400 lbs/day BOD_5 and 19,500 lbs/day TKN. Other (1969) observed waste constituent totals included:

2,020 lbs/day total phosphates,
440 lbs/day ortho phosphates,
28,700 lbs/day total suspended solids, and
10,140 lbs/day volatile suspended solids.

[1/] Numbers in parentheses refer to bibliography references.

The State of Tennessee Division of Stream Pollution Control collected data on three of the major waste sources in 1960:

Tennessee Eastman discharged 75,000 lbs/day BOD_5;

Mead Paper Company discharged 25,000 lbs/day BOD_5; and

City of Kingsport discharged 11,250 lbs/day BOD_5 (2).

Data were not available from Holston Army Ammunition Plant or Holliston Mills.

By July 1969, the Tennessee Eastman Corporation had effected in-plant recovery and had constructed an aeration pond with approximately five days waste capacity. The Corporation presently has under construction a cooling tower which will substantially reduce contaminated cooling water discharges. Based on the June-July 1969 survey data, Tennessee Eastman discharges 69,300 lbs/day BOD_5, or a reduction of 7.5 percent from the 1960 values. This represents 49.3 percent of the BOD_5 from all waste discharges.

The Mead Paper Company has also developed in-plant recovery procedures and installed a clarifier for primary waste treatment. In September 1970 the Company was closing down part of its paper production in Kingsport and the details of necessary additional treatment will be reevaluated by Mead upon analysis of the new waste effluent. During June-July 1969, the Mead Paper Company discharged 11,700 lbs/day BOD_5, representing a 53 percent reduction from 1960 values. The 1969 BOD_5 waste load was 8.3 percent of the total discharged from the five sources.

The City of Kingsport was discharging raw waste in 1960. Presently, the city provides secondary treatment with discharge into Reedy Creek, a small tributary of the South Fork. The waste effluent measured by FWQA (now EPA) during June-July 1969 was 500 lbs/day BOD_5. This is a 95.5 percent reduction from 1960 and 0.4 percent of the BOD_5 from all waste discharges considered. Plant records during the summer of 1969 show an average effluent of 600 pounds per day.

Holston Army Ammunition Plant has begun a program of in-plant recovery and on-site impoundment primarily for the ammonia waste. During the 1969 survey, it contributed 39.7 percent of the BOD_5.

Holliston Mills has received a research and demonstration grant from EPA to develop a process for very high removal efficiencies from its textile wastes. Although the waste flow is relatively small, the BOD_5 concentration was 1,005 milligrams per liter (mg/l) -- obviously in need of great reduction.

A summary of the BOD_5 and TKN discharges and their sources is presented in Table 4. Detailed waste discharge findings of this survey are presented in Appendix B.

Table 4
Summary of Point Source Waste Discharges
BOD$_5$ and TKN

Waste	Raw Waste Estimates		1969 Findings			
	BOD$_5$		BOD$_5$		TKN	
Source	lbs/day	% of total	lbs/day	% of total	lbs/day	% of total
Tenn. Eastman	75,000	43.1	69,300	49.3	16,120	83.0
Mead	25,000	14.7	11,700	8.3	60	0.3
Kingsport S.T.P.	11,250	6.6	500	0.4	160	0.8
HAAP						
Area A	23,480	13.8	23,480	16.7	10	0.05
Area B	32,220	18.9	32,220	23.0	3,045	15.7
Holliston Mills	3,200 *	1.9 *	3,200 *	2.3 *	30 *	0.15 *
TOTAL	170,150	100.0	140,400	100.0	19,425	100.0

* These figures may be too great by a factor of ten. Nevertheless the overall results still hold because this waste (even overstated) is relatively insignificant.

STREAM SURVEY RESULTS

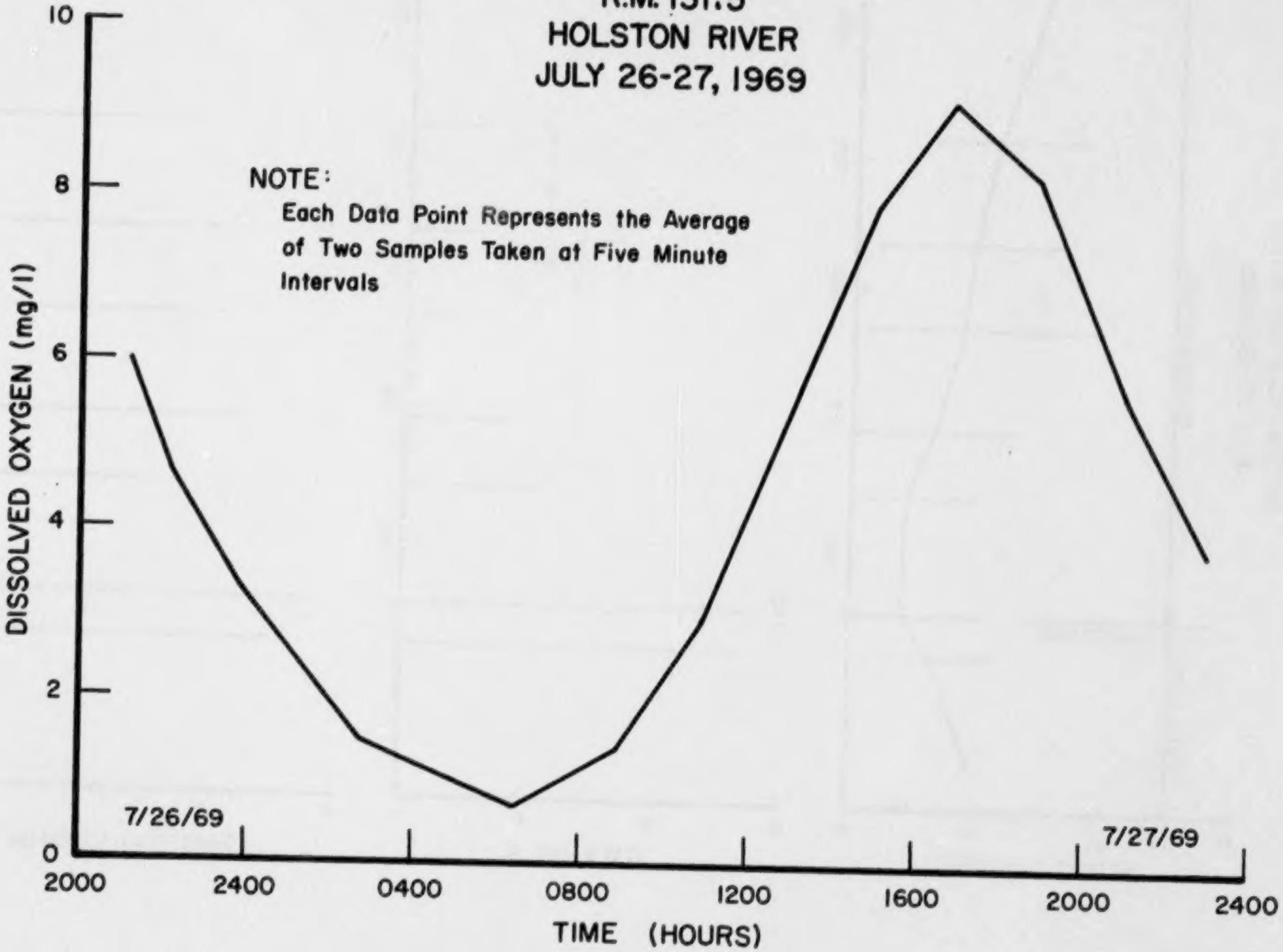
In the reach from RM 1-2 on the South Fork to Holston RM 135.5, dissolved oxygen levels approached zero in many locations. Extensive photosynehesis and respiration effects were indicated in the extreme DO variability observed in "round-the-clock" measurements. A typical dissolved oxygen diurnal curve is shown in Figure 4 for RM 131.5. At this station, DO was less than 3 mg/l for about 11 hours in a 24-hour period.

Values of BOD_5 and TKN jumped to highs of 17.5 mg/l and 3.59 mg/l, respectively, in the vicinity of waste discharges. Figure 5 shows the DO variations as well as the BOD_5 and TKN values in the study area. High values of TKN were much more persistent than those of BOD_5 (as would be expected with the lower "k" rate for nitrification). Tabular data and a detailed discussion of water quality data are included in Appendix C.

The benthic demand on dissolved oxygen upstream of waste sources in the South Fork is 85 pounds per day per square mile. In the Holston River, below the confluence of the North and South Forks, and downstream of the waste sources at Kingsport, the benthic demand is 500 pounds per day per square mile. In the reach of river 17 to 23 miles downstream of the confluence the benthic demand averaged 3,360 pounds per day per square mile. A significant portion of this benthic demand results from the discharge of organic material from the waste sources in the Kingsport area.

FIGURE 4

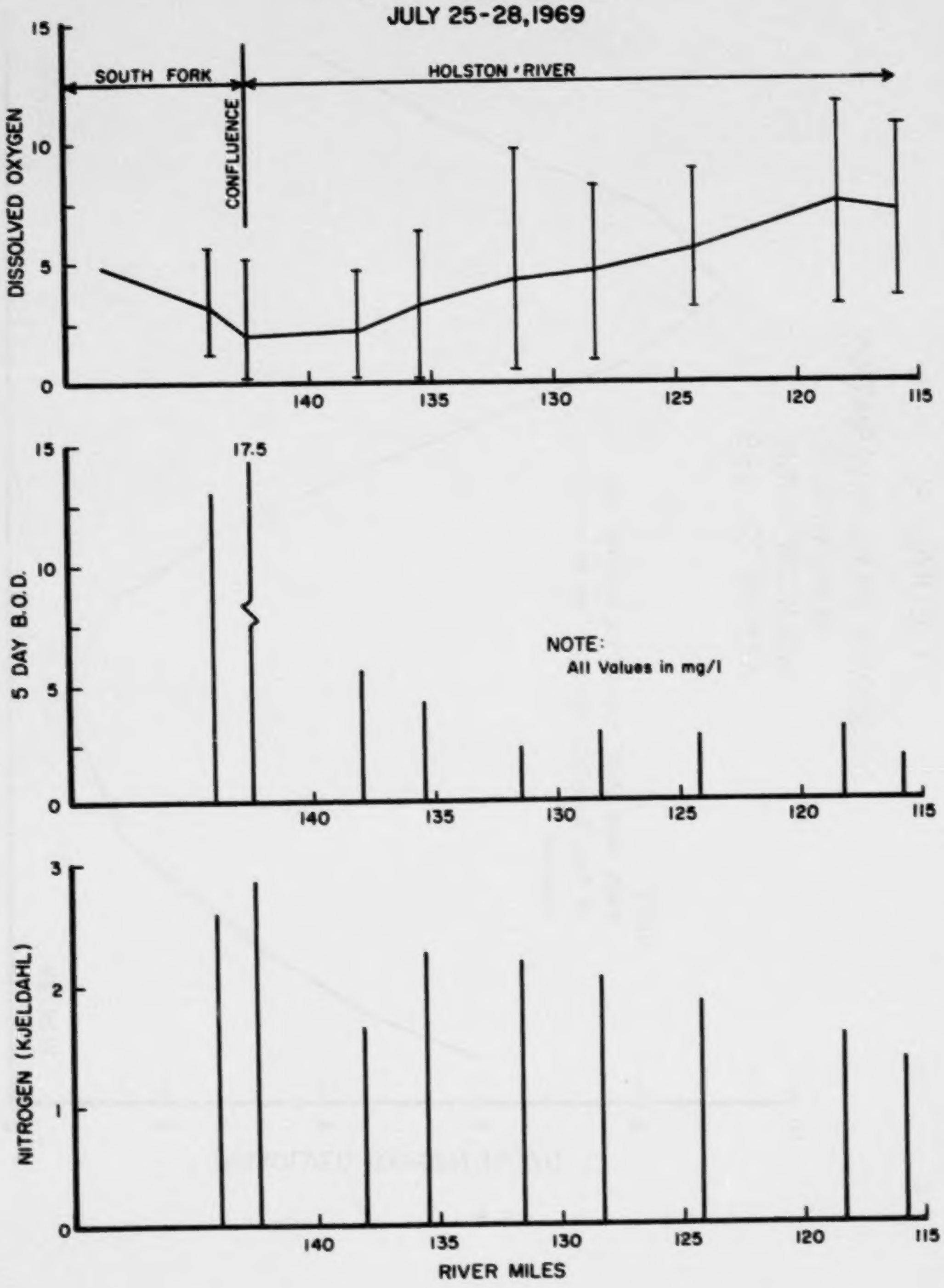
DISSOLVED OXYGEN VARIATION
R.M. 131.5
HOLSTON RIVER
JULY 26-27, 1969



NOTE:
Each Data Point Represents the Average of Two Samples Taken at Five Minute Intervals

FIGURE 5

MEAN WATER QUALITY
UPPER HOLSTON RIVER
JULY 25-28,1969



NOTE:
All Values in mg/l

Benthic oxygen demands were quite variable since their locations and intensities are the result of:

- the locations and amounts of discharges or organic solids,
- areas of intensive aquatic weed growths,
- areas favoring sedimentation of suspended solids.

Appendix D contains a more detailed discussion, tabular data, and a somewhat arbitrarily assumed distribution of benthic oxygen demand employed in mathematical simulation of stream conditions.

Attached aquatic plants in the study area during June 1969 weighed approximately 170 tons (wet weight). Downstream of RM 135.4 the standing crop was 21% greater than upstream from this point in the Holston River. This density variation corresponded to the distribution of nitrates, which were 84% greater downstream than upstream from this point. Appendix E includes a detailed discussion of the "Biological Standing Corp".

STREAM SIMULATION

A. Theory

The mathematical model used in this study for predicting dissolved oxygen concentrations is based on the classical Streeter-Phelps equation:

$$\frac{dD}{dt} = k_r L - k_2 D + B - (P-R) + k_n N \qquad (1)$$

where L = ultimate BOD

k_r = BOD oxidization rate in the river

D = DO deficit (from saturation under existing conditions)

k_2 = reaeration rate

B = benthic oxygen demand

$P-R$ = photosynthesis less respiration

N = nitrogenous oxygen demand

k_n = oxidization rate of nitrogenous material

$\frac{dD}{dt}$ = rate of change with time of downstream waste travel) of DO deficit

Integration yields:

$$Dt = \frac{K_r L_o}{k_2-k_r}\left(10^{-k_r t} - 10^{-k_2 t}\right) + \frac{k_n N_o}{k_2-k_n}\left(10^{-k_n t} - 10^{-k_2 t}\right)$$

$$+ \frac{B}{k_2}\left(1-10^{-k_2 t}\right) + \frac{P-R}{k_2}\left(1-10^{-k_2 t}\right) + D_o\left(10^{-k_2 t}\right) \qquad (2)$$

where D_t = dissolved oxygen deficit at time of travel, t

L_o = total concentration of ultimate BOD in the river

N_o = total amount of unsatisfied nitrogenous material in the river as equivalent oxygen

D_o = initial dissolved oxygen deficit

o = refers to conditions at the beginning of each reach of river where the equation was applied.

Appendix F contains a detailed discussion of the application of this equation to the study area. Dissolved oxygen was predicted for the initial conditions and the various waste discharges.

B. Results

A 90 percent reduction of both BOD_5 and TKN based on July 1969 waste sources is required to allow the DO to recover to 5 mg/l at the end of the sag zone as set by Tennessee Stream Standards (Figure 2). Many of the calculations discussed here were based on treatment required to meet the minimum DO allowable in the sag zone.

However, the minimum in the sag zone is not the critical consideration here; recovery by the end of the designated sag zone (R.M. 131.5) requires more stringent waste reduction, and the actual DO sag point will move downstream in winter, shortening the distance available for necessary recovery. Calculated requirements for meeting sag zone minimums must be extrapolated upwards for recovery requirements.

Reductions of 92 percent of the raw waste BOD_5 values and 92 percent of the major sources of TKN are required as discussed earlier under "Findings", "Conclusions", "Rationale", and "Waste Discharges".

Appendix F contains the remainder of the simulation results.

BIBLIOGRAPHY

1. Wezernak, C. J., and J. J. Gannon, "Oxygen-Nitrogen Relationships in Autotrophic Nitrification," *Applied Microbiology*, *15*, 1211-1215, (Sept), 1967.

2. Personal Communication, Mr. Robert Hunt, Regional Engineer, Tennessee Division of Stream Pollution Control, Knoxville, Tennessee.

APPENDICES

A. GENERAL WATER QUALITY CRITERIA FOR THE DEFINITION AND CONTROL OF POLLUTION IN THE WATERS OF TENNESSEE.

B. WASTE DISCHARGES - UPPER HOLSTON RIVER.

C. WATER QUALITY - UPPER HOLSTON RIVER.

D. BENTHIC SEDIMENT DEMAND.

E. BIOLOGICAL STANDING CROP.

F. MATHEMATICAL MODEL.

G. SAMPLING PROCEDURE.

H. SUMMARY OF OBSERVED DATA.

Appendix A

GENERAL WATER QUALITY CRITERIA FOR THE DEFINITION AND CONTROL OF POLLUTION IN THE WATERS OF TENNESSEE

Adopted on May 26, 1967

Tennessee Stream Pollution Control Board
(now Tennessee Water Quality Control Board)

Fully Approved on June 2, 1972
by the
Environmental Protection Agency

Tennessee Code Annotated, Sections 70-301 through 70-319, makes it the duty of the Stream Pollution Control Board to study and investigate all problems concerned with the pollution of the waters of the State and with its prevention, abatement, and control and to establish such standards of quality for any waters of the State in relation to their reasonable and necessary use as the Board shall deem to be in the public interest and establish general policies relating to existing or proposed future pollution as the Board shall deem necessary to accomplish the purpose of the Control Code. The following general considerations and criteria are officially adopted by the Board as a guide in determining the permissible conditions of waters with respect to pollution and the preventive or corrective measures required to control pollution in various waters or in different sections of the same waters.

GENERAL CONSIDERATIONS

1. Waters have many uses which in the public interest are reasonable and necessary. Such uses include: sources of water supply for domestic and industrial purposes: propagation

and maintenance of fish and other desirable aquatic life: recreational boating and fishing; the final disposal of municipal sewage and industrial waste following adequate treatment; stock watering and irrigation; navigation; generation of power; and the enjoyment of scenic and esthetic qualities of the waters.

2. The rigid application of uniform water quality is not desirable or reasonable because of the varying uses of such waters. The assimilative capacity of a stream for sewage and waste varies depending upon various factors including the following: volume of flow, depth of channel, the presence of falls or rapids, rate of flow, temperature, natural characteristics, and the nature of the stream. Also the relative importance assigned to each use will differ for different waters and sections of waters throughout the stream.

3. To permit reasonable and necessary uses of the water of the State, existing pollution should be corrected as rapidly as practical and future pollution controlled by treatment plants or other measures. There is an economical balance between the cost of sewage and waste treatment and the benefits received and within permissible limits the dilution factor and the assimilative capacity of surface water should be utilized. Waste recovery, control of rates and dispersion of waste into the streams, and control of rates and characteristics of flow of waters in the stream where adequate, will be considered to be a means of correction.

4. Sewage, industrial wastes, or other wastes, as defined in the Stream Pollution Control Code, shall not be discharged into or adjacent to streams or other surface waters in such quantity and of such character or under such conditions of discharge in relation to the receiving waters as will result in visual or olfactory nuisances, undue interference to other reasonable and necessary uses of the water, or appreciable damage to the natural processes of self-purification. In relation to the various qualities and the specific uses of the receiving waters, no sewage, industrial wastes, or other wastes discharged shall be responsible for conditions that fail to meet the criteria of water quality outlined below. Bypassing or accidental spills will not be tolerated.

5. The criteria of water quality outlined below are considered as guides in applying the water quality objectives in order to insure reasonable and necessary uses of the waters of the State. In order to protect the public health and maintain the water suitable for other reasonable and necessary uses: to provide for future development; to allow proper sharing of available water resources; and to meet the needs of particular situations, additional criteria will be set.

CRITERIA OF WATER CONDITIONS

1. Domestic Raw Water Supply

(a) Dissolved Oxygen -- There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH -- The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Hardness or Mineral Compounds -- There shall be no substances added to the waters that will increase the hardness or mineral content of the waters to such an extent to appreciably impair the usefulness of the water as a source of domestic water supply.

(d) Total Dissolved Solids -- The total dissolved solids shall at no time exceed 500 mg/l.

(e) Solids, Floating Materials, and Deposits -- There shall be no distinctly-visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water as a source of domestic water supply.

(f) Turbidity or Color -- There shall be no turbidity or color added in amounts or characteristics that cannot be reduced to acceptable concentrations by conventional water treatment processes.

(g) Temperature -- The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed

30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(h) Microbiological Coliform -- Coliform group shall not exceed 10,000 per 100 ml. as a monthly average value (either MPN or MF count); nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml. in more than five percent of such samples. These values may be exceeded provided the organisms are known to be of nonfecal origin. No disease producing bacteria or other objectionable organisms shall be added to surface waters which will result in the contamination of said waters to such an extent as to render the water unsuitable as sources of domestic water supply after conventional water treatment.

(i) Taste or Odor -- There shall be no substances added which will result in taste or odor that prevent the production of potable water by conventional water treatment processes.

(j) Toxic Substances -- There shall be no toxic substances added to the waters that will produce toxic conditions that materially affect man or animals or impair the safety of a conventionally-treated water supply.

(k) Other Pollutants -- Other pollutants shall not be added to the water in quantities that may be detrimental to public health or impair the usefulness of the water as a source of domestic water supply.

2. Industrial Water Supply.

(a) Dissolved Oxygen — There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH -- The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Hardness or Mineral Compounds -- There shall be no substances added to the waters that will increase the hardness or mineral content of the waters to such an extent as to appreciably impair the usefulness of the water as a source of industrial water supply.

(d) Total Dissolved Solids — The total dissolved solids shall at no time exceed 500 mg/1.

(e) Solids, Floating Materials and Deposits — There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water as a source of industrial water supply.

(f) Turbidity or Color -- There shall be no turbidity or color added in amounts or characteristics that cannot be reduced to acceptable concentrations by conventional water treatment processes.

(g) Temperature -- The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(h) Taste or Odor -- There shall be no substances added that will result in taste or odor that would prevent the use of the water for industrial processing.

(i) Toxic Substances -- There shall be no substances added to the waters that may produce toxic conditions that will adversely affect the water for industrial processing.

(j) Other Pollutants -- Other pollutants shall not be added to the waters in quantities that may adversely affect the water for industrial processing.

3. Fish and Aquatic Life

(a) Dissolved Oxygen -- The dissolved oxygen shall be maintained at 5.0 mg/l except in limited sections of the stream receiving treated effluents. In these limited sections, a minimum of 3.0 mg/l dissolved oxygen shall be allowed. The dissolved oxygen content shall be measured at mid-depth in waters having a total depth of ten (10) feet or less and at a depth of five (5) feet in waters have a total depth of greater than ten (10) feet. A minimum dissolved oxygen content of 6.0 mg/l shall be maintained in recognized trout streams.

(b) pH -- The pH value shall lie within the range of 6.5 to 8.5 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Solids, Floating Materials and Deposits -- There shall be no distinctly visible solids, scum, foam, oily sleek, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to fish and aquatic life.

(d) Turbidity or Color -- There shall be no turbidity or color added in such amounts or of such character that will materially affect fish and aquatic life.

(e) Temperature -- The maximum water temperature change shall not exceed $3^{o}C$ relative to an upstream control point. The temperature of the water shall not exceed $30.5^{o}C$ and the maximum rate of change shall not exceed $2^{o}C$ per hour. The temperature of recognized trout waters shall not exceed $20^{o}C$. There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(f) Taste or Odor -- There shall be no substances added that will impart unpalatable flavor to fish or result in noticeable offensive odors in the vicinity of the water or otherwise interfere with fish or aquatic life.

(g) Toxic Substances -- There shall be no substances added to the waters that will produce toxic conditions that affect fish or aquatic life.

(h) Other Pollutants -- Other pollutants shall not be added to the waters that will be detrimental to fish or aquatic life.

4. Recreation

(a) Dissolved Oxygen -- There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH -- The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Solids, Floating Materials, and Deposits -- There shall be no distinctly-visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character that may be detrimental to recreation.

(d) Turbidity or Color -- There shall be no turbidity or color added in such amounts or character that will result in an objectionable appearance to the water.

(e) Temperature -- The maximum water temperature change shall not exceed 3°C relative to an upstream control point. The temperature of the water shall not exceed 30.5°C and the maximum rate of change shall not exceed 2°C per hour. The temperature of impoundments where stratification occurs will be measured at a depth of 5 feet, or mid-depth whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

(f) Microbiological Coliform -- The fecal coliform group shall not exceed 5,000 per 100 ml as a monthly average value nor exceed this number in more than 20 percent of the samples examined during any month; nor exceed 20,000 per 100 ml in more than five percent of such samples. In those waters that are physically suitable and available to the public for water-contact recreation, the fecal coliform concentration shall not exceed 1,000 per 100 ml in any two consecutive samples collected during the months of May through September. Water areas near outfalls of domestic sewage treatment plants are not considered suitable for water-contact recreation.

(g) Taste or Odor -- There shall be no substances added that will result in objectionable taste or odor.

(h) Toxic Substances -- There shall be no substances added to the water that will produce toxic conditions that affect man or animal.

(i) Other Pollutants -- Other pollutants shall not be added to the water in quantities which may have a detrimental effect on recreation.

5. Irrigation

(a) Dissolved Oxygen -- There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) pH -- The pH value shall lie within the range of 6.0 to 9.0 and shall not fluctuate more than 1.0 unit in this range over a period of 24 hours.

(c) Hardness or Mineral Compounds -- There shall be no substances added to the water that will increase the mineral content to such an extent as to impair its use for irrigation.

(d) Solids, Floating Materials, and Deposits -- There shall be no distinctly visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as may impair the usefulness of the water for irrigation purposes.

(e) Temperature -- The temperature of the water shall not be raised or lowered to such an extent as to interfere with its use for irrigation purposes.

(f) Toxic Substances -- There shall be no substances added to the water that will produce toxic conditions that will affect the water for irrigation.

(g) Other Pollutants -- Other pollutants shall not be added to the water in quantities which may be detrimental to the water for livestock watering and wildlife.

7. Navigation

(a) Dissolved Oxygen -- There shall always be sufficient dissolved oxygen present to prevent odors of decomposition and other offensive conditions.

(b) Hardness or Mineral Compounds -- There shall be no substances added to the water that will increase the mineral content to such an extent as to impair its use for navigation.

(c) Solids, Floating Materials, and Deposits -- There shall be no distinctly-visible solids, scum, foam, oily slick, or the formation of slimes, bottom deposits or sludge banks of such size or character as to interfere with navigation.

(d) Temperature -- The temperature of the water shall not be raised or lowered to such an extent as to interfere with its use for navigation purposes.

(e) Toxic Substances -- There shall be no substances added to water that will produce toxic conditions that will affect the water for navigation.

(f) Other Pollutants -- Other pollutants shall not be added to the water in quantities which may be detrimental to the waters used for navigation.

These criteria should not be construed as permitting the degradation of higher quality water when such can be prevented by reasonable pollution control measures. The above conditions are recognized as applying to waters affected by the discharge of sewage and/or industrial waste or other waste and not resulting from natural causes.

DEFINITIONS

1. Conventional Water Treatment -- Conventional water treatment as referred to in the criteria denotes coagulation, sedimentation, filtration and chlorination.
2. Mixing Zone -- Mixing zone refers to that section of flowing stream or impounded waters necessary for effluents to become dispersed.
3. The mixing zone necessary in each particular case shall be defined by the Tennessee Water Quality Control Board.

INTERPRETATION OF CRITERIA

1. Interpretations of the above criteria shall conform to any rules and regulations or policies adopted by the Water Quality Control Board.

2. Insofar as practicable, the effect of treated sewage or waste discharges on the receiving waters shall be considered after they are mixed with the waters and beyond a reasonable zone of immediate effect upon the qualities of the waters. The extent to which this is practicable depends upon local conditions and the proximity and nature of other uses of the waters.
3. The technical and economical feasibility of waste treatment, recovery, or adjustment of the method of discharge to provide correction shall be considered in determining the time to be allowed for the development of practicable methods and for the specified correction.
4. The criteria set forth shall be applied on the basis of the following stream flows: unregulated streams -- stream flows equal to or exceeding the 3-day minimum, 20-year recurrence interval; regulated streams -- instantaneous minimum flow.
5. In general, deviations from normal water conditions may be undesirable, but the rate and extent of the deviations should be considered in interpreting the above criteria.

TENNESSEE ANTIDEGRADATION STATEMENT

1. The Standards and Plan adopted are designed to provide for the protection of existing water quality and/or the upgrading or "enhancement" of water quality in all waters within Tennessee. It is recognized that some waters may have existing quality better than established standards.

2. The Criteria and Standards shall not be construed as permitting the degradation of these higher quality waters when such can be prevented by reasonable pollution control measures. In this regard, existing high quality water will be maintained unless and until it is affirmatively demonstrated to the Tennessee Water Quality Control Board that a change is justifiable as a result of necessary social and economic development.
3. All discharges of sewage, industrial waste, or other waste shall receive the best practicable treatment (secondary or the equivalent) or control according to the policy and procedure of the Tennessee Water Quality Control Board. A degree of treatment greater than secondary when necessary to protect the water uses will be required for selected sewage and waste discharges.
4. In implementing the provisions of the above as they relate to interstate streams, the Tennessee Water Quality Control Board will cooperate with the appropriate Federal Agency in order to assist in carrying out responsibilities under the Federal Water Pollution Control Act, as amended.

Appendix B

WASTE DISCHARGES
UPPER HOLSTON RIVER
Oxygen Demand and Carbonaceous Material

Waste Source	Flow (mgd)1/	Biochemical Oxygen Demand2/ Lbs/day	P.E.3/	% Contribution4/	Total Organic Carbon Lbs/day	% Contribution4/
Tenn. Eastman Corp.						
A. South Plant	6.6	17500	102900		3420	
B. Long Island	8.7	14600	85900		5280	
C. Hales Branch	25.4	37200	218800		4250	
Total	40.7	69300	407600	49.3	12950	42.2
Mead Paper Co.	9.4	11700	68800	8.3	2760	9.0
Kingsport S. T. P.	2.4	500	2900	0.4	1.3	
Holston Army Ammunition Plant						
A. Area A						
1. Main Effluent	55.1	22900	134700		4190	
2. Composite Line	4.4	3410		60		
Sub Total	59.5	23480	138110		4250	
B. Area B						
1. Water Plant	12.8					
Backwash	5.4	1710	10060		430	
2. Line 3-A	4.1	10480	61600		5760	
3. Line 3-B	3.2	3750	22100		1470	
4. Line 3-C	77.5	2740	16100		340	
5. Monitor Ditch	103.0	13540	79600		2140	
Sub Total	162.5	32220	189460		10140	
Total		55700	327570	39.7	14390	46.8
Holliston Mills *	0.38	3200	18800	2.3	200	0.7
South Fork	543	10900	64100		4540	
North Fork	660	10700	63000		10700	

1/ mgd = million gallons per day.

2/ All BOD values are five day at 20°C.

3/ Population equivalent = 0.17 lbs. per capita per day.

4/ percentages are based on point sources only and do not include contributions from North and South Forks, upstream of waste discharges.

* These waste discharge figures may be too great by a magnitude; but even overstated, this waste is relatively insignificant and a correction would not change the results.

Appendix B (Cont)
WASTE DISCHARGES
UPPER HOLSTON RIVER
Nitrogenous Material

Waste Source	Total Kjeldahl N. Lbs/day	Total Kjeldahl N. % Contrib.	Ammonia N. Lbs/day	Ammonia N. % Contrib.	Nitrite-Nitrate N Lbs/day	Nitrite-Nitrate N % Contrib.	Total N Lbs/day	Total N P E 3/
Tenn. Eastman Corp.								
A. South Plant	2/		-- 2/		-- 2/			
B. Long Island	11910		10120		-- 2/			
C. Hales Branch	4210		660		-- 2/			
Total	16120	83.0	10780	78.5	-- 2/	0	16120	672000
Mead Paper Co.	60	0.3	-- 2/	0	-- 2/	0	60	2500
Kingsport S.T.P.	160	0.8	110	0.8	20	1.0	180	7500
Holston Army Ammunition Plant								
A. Area A								
1. Main Effluent	-- 2/		-- 2/		-- 2/			
2. Composite Line	10		10		-- 2/			
Sub Total	10		10		-- 2/		10	
B. Area B								
1. Water Plant Backwash	130		60		40		170	
2. Line 3-A	65		-- 2/		80		145	
3. Line 3-B	70		60		130		130	
4. Line 3-C	20		-- 2/		30		50	
5. Monitor Ditch	2760		2760		2250		5010	
Sub Total	3045		2820		2460		5505	
Total	3055	15.7	2830	20.6	2460	99.0	5515	230000
Holliston Mills*	30	0.2	-- 2/	0	-- 2/	0	30	1250
South Fork	1770		410		5670		7440	
North Fork	1390		200		3600		4990	

1/ Percent contribution from point waste sources only.

2/ Not significantly above raw water intake amounts.

3/ One population equivalent = .024 pounds per capita per day.

* See note at start of appendix

Appendix B (Cont)

WASTE DISCHARGES
UPPER HOLSTON RIVER
Phosphorus and Suspended Solids

Waste Source	Total P1/			Ortho P		Total S. Solids		Volatile S. Solids	
	Lbs/da	P E 2/	% Cont.3/	Lbs/da	% Cont.	Lbs/da	% Cont.	Lbs/day	% Cont.
Tenn. Eastman Corp.									
A. South Plant	--	--		--		2550		94	
B. Long Island	507	63400		302		5230		4465	
C. Hales Branch	1277	160000		--		--		--	
Total	1784	223400	88.5	302	67.9	7780	27.1	4559	45.0
Mead Paper Co.	4	500	0.2	4	0.9	11430	39.9	3092	30.5
Kingsport S.T.P.	152	19000	7.5	110	24.7	440	1.5	240	2.4
Holston Army Ammunition Plant									
A. Area A									
1. Main Effluent	27	3380		--		4100		--	
2. Composite Line	2	250		--		--		--	
Sub Total	29	3630		--		4100		--	
B. Area B									
1. Water Plant Backwash	27	3380		13		2690		760	
2. Line 3-A	--	--		--		1210		780	
3. Line 3-B	--	--		--		640		470	
4. Line 3-C	--	--		--		300		190	
5. Monitor Ditch	--	--		--		--		--	
Sub Total	27	3380		13		4840		2200	
Total	56	7010	2.8	13	2.9	8940	31.2	2200	21.7
Holliston Mills *	21	2630	1.0	16	3.6	89	0.3	48	0.4
South Fork	141	17650		91		62140		37650	
North Fork	107	13400		43		31000		10700	

1/ As phosphorus

2/ One population equivalent = .008 pounds per capita per day

3/ % Contribution from point waste sources only

* See note at start of appendix

Appendix C

WATER QUALITY - UPPER HOLSTON RIVER

A. Physical

During the stream sampling period, the flow from the North Fork of the Holston River measured at Gate City averaged 660 cfs with a range beween 890 cfs and 490 cfs. The discharge uniformly receded during the four days of sampling from the high to low figure. Discharge from the South Fork, which is regulated by Fort Patrick Henry Dam, was held constant at 760 cfs on a daily average basis. The customary release cycle was followed: no flow for three hours and discharge at a constant rate slightly in excess of 3,000 cfs during the fourth hour. Local accrual including discharge from Reedy Creek increased average stream flow in the South Fork below mile 1.2 to 840 cfs.

A time of travel study was conducted using dye tracer during the sampling period (Table C-1). The peak of the dye curve was considered the time of travel. A relationship between discharge rates and time of travel was developed in the Holston River from previous studies conducted in 1945 by TVA and expressed as:

$$t_2 = t_1 \left(\frac{Q_1}{Q_2}\right)^{-b}$$

where t = time of travel in hours

Q = mean stream flow in cfs

b = inverse of the slope resulting from log Q vs. log $(\frac{1}{t})$

The value of b was 0.674 from the confluence to RM 131.5 and 0.539

Table C-1

TIME OF TRAVEL AND TEMPERATURE

UPPER HOLSTON RIVER*

July 25-28, 1969

River Reach (River Miles)	Time of Travel (Days)	Cumulative Time of Travel (Days)	Temperature (°C)	
			Max.	Min.
South Fork				
RM 1.2	0.0		30.0	20.1
Holston River				
Confluence				
(RM 142.2)	0.167	0.167		
RM 137.9	0.263	0.430	28.0	24.0
RM 135.4	0.242	0.672	30.0	26.5
RM 131.5	0.167	0.839	29.5	25.0
RM 128.3	0.210	1.049	29.2	23.0
RM 124.3	0.302	1.351	28.0	23.5
RM 118.4	0.573	1.924	30.0	25.0

* Average flow = 840 cfs in South Fork
660 cfs in North Fork

from RM 131.5 to RM 118.4. These values were employed to estimate time of travel in projecting probable water quality at other flows.

Water released from Fort Patrick Henry Dam had an average temperature of 15.5°C during the survey. Historical data show that the temperature is rarely in excess of 17°C. At RM 1.2 in the South Fork, downstream of the major sources of waste, the average temperature was 26.5°C. The average temperature in the North Fork just upstream of the confluence was 27.0°C. Water temperature remained fairly constant in the study area averaging between 26° and 28°C at each sampling location. However, at night temperatures were recorded in the low-20 range and near or at 30°C during the day.

B. Chemical

Five-day BOD in the South Fork increased from 2.4 mg/l at RM 5.6 to 17.5 mg/l at RM 1.2 as the result of industrial and municipal waste discharges at Kingsport. The BOD_5 concentration in the North Fork was 3.4 mg/l at RM 0.1 (Table C-1). The influence of the HAAP Area B waste discharge is demonstrated by the level of 5.5 mg/l on the left side of the channel looking downstream and 14.0 mg/l on the right side. There is a rapid decline of BOD_5 to near background levels of 2 to 3 mg/l by the end of the sag zone at RM 131.5.

Total Kjeldahl nitrogen concentrations in the South Fork increased more than six times over background levels due to waste discharges, primarily from Tennessee Eastman Company, which contributed 83 percent of the total. The value of 2.67 mg/l observed at South Fork RM 1.2 included 2.01 mg/l ammonia (as N), 20 times the background level.

Background concentrations of nitrates were quite high, averaging 1.25 mg/1 (as N) at RM 5.6 in the South Fork and 1.01 mg/1 at RM 0.1 in the North fork. The contribution of Kjeldahl nitrogen from HAAP Area B is indicated by the level of 1.65 mg/1 on the side of the river unaffected by the discharge and 3.95 mg/1 immediately downstream of the discharge (RM 137.9). Nitrate followed the same pattern increasing from 0.60 mg/1 to 2.38 mg/1. All Kjeldahl and ammonia nitrogen concentrations decreased downstream of RM 137.9. However, at RM 115.9, Kjeldahl nitrogen values were still about three and a half times greater than background, and ammonia concentrations were nine times greater than background (Table C-2). Nitrates decreased to 0.89 mg/1 at RM 131.5 and then increased to 1.49 mg/1 through four sampling locations downstream to RM 115.9.

Total and phosphorus orthophosphate (as P) were increased eight and six times respectively in the South Fork over levels discharged from Fort Patrick Henry Dam. The average concentrations at RM 1.2 were 0.25 mg/1 total phosphorus and 0.12 mg/1 orthophosphate (P). Concentrations decreased in the Holston River throughout the study area. At RM 115.9 total phosphorus and orthophosphate (P) were about twice background values at 0.06 mg/1 and 0.04 mg/1 respectively.

TABLE C-2

MEAN WATER QUALITY UPPER HOLSTON RIVER

July 25-28, 1969

River Mile	Dissolved Oxygen Mean	Dissolved Oxygen Max	Dissolved Oxygen Min	BOD 2-day	BOD 5-day	Nitrogen (as N) Kjeldahl	Nitrogen (as N) NH_3	Nitrogen (as N) NO_2-NO_3	Phosphorus (as P) Total	Phosphorus (as P) Ortho
South Fork										
R.M. 5.6	4.9	5.3	4.7	1.4	2.4	0.39	0.10	1.25	0.03	0.02
R.M. 1.2	3.2	5.7	1.2	11.3	17.5	2.67	2.01	0.88	0.25	0.12
North Fork										
R.M. 0.1	8.8	11.3	6.2	1.6	3.4	0.39	0.08	1.01	0.03	0.01
Holston River										
R.M. 141.2	1.8	5.2	0.1	6.3	9.9	2.28	1.68	0.63	0.20	0.07
R.M. 137.9[1/]	2.1	4.5	0.2	3.5	5.5	1.65	1.24	0.60	0.13	0.06
R.M. 137.9[2/]	--	--	--	10.9	14.0	3.59	2.76	2.38	0.10	0.04
R.M. 135.4	3.2	6.3	0.3	2.0	4.3	2.28	1.85	0.95	0.09	0.04
R.M. 131.5	4.3	9.7	0.6	1.2	2.3	2.20	1.79	0.89	0.07	0.04
R.M. 128.3	4.6	8.2	0.9	1.6	2.9	2.07	1.65	1.02	0.06	0.03
R.M. 124.3	5.5	8.8	3.2	1.1	2.7	1.84	1.48	1.13	0.06	0.03
R.M. 118.4	7.5	11.7	3.3	1.7	3.1	1.58	1.10	1.31	0.06	0.03
R.M. 115.9	7.1	10.6	3.6	0.8	1.8	1.37	0.91	1.49	0.06	0.04

1/ Left side of channel only - no HAAP Area B waste.

2/ Right side of channel - reflects HAAP Area B waste.

NOTE: All values expressed as milligrams per liter (mg/1).

Appendix D

BENTHIC SEDIMENT DEMAND

Rates of oxygen uptake by bottom sediments were measured at various locations on the Holston River and its tributaries from Kingsport downstream to the impoundment for the John Sevier steam plant intake (RM 109.9). Rates were determined by recording dissolved oxygen depletion inside closed chambers seated over small areas of the bottom during each period. These data, corrected to 20°C, are listed in Tables D-1 and D-2.

Benthic oxygen demands on the South Fork, upstream of the industrial outfalls, were 1.5 and 0.9 grams per square meter per day at 20°C. The North Fork demand was 2.4 grams per square meter per day at RM 141.1 to 1.3 grams per square meter per day at RM 115.3 mid-channel. The demand increased to 3.8 grams per square meter per day at mid-channel of RM 109.9, reflecting an area of deposition in the backwater of the steam plant reservoir. The high value at RM 109.9 near the left bank is considered unrepresentative due to sediment disturbance. The profile of benthic oxygen demand is illustrated in Figure D-1.

TABLE D-1

BENTHIC OXYGEN DEMAND OF SEDIMENT DEPOSITS

IN THE

HOLSTON RIVER BELOW KINGSPORT, TENNESSEE

EPA DATA, REGION IV, SURVEILLANCE AND ANALYSIS DIVISION

Mile	Horizontal Location	Water Depth	Date 1969	Approx. Time	Rate at Temp. & DO gm/m^2/day	°C	mg/l	Rate at 20°C[1] gm/m^2/day	% Carbon (dry weight)	Remarks
South Fork at Hwy 93 Bridge	midchannel	10	6/24	1600	2.3	27	6.8	1.5	14.0	
South Fork 2 to 3 miles above Hwy 93 Bridge	near shore	1	6/24	1700	1.2	24	7.0	0.9	3.9	
North Fork 0.1	midchannel	3	6/24	0900	3.7	27	7.0	2.4	6.7	
141.8	near shore	15	6/23	--	7.4	27	7.4	4.8	6.7	Silt ooze
141.1	near shore	3	6/24	1000	16.0	27	4.0	10.3	7.7	Sludge & bloodworms
138.3	near shore	3	6/24	1130	12.1	21	3.2	11.4	10.0	Sludge
134.0	bank	2	6/20	1300	4.6	22	7.5	4.1	5.7	Sludge worms
134.0	midchannel	2	6/20	1330	5.6	22	7.0	4.9	0.5	
133.3	near shore	--	6/20	1400	4.6	19	7.8	4.9	5.1	
132.5	midchannel	4	6/20	1500	2.3	19	9.8	2.5	--	
131.6	midchannel	8	6/20	1600	4.6	20	7.5	4.6	4.6	
128.3	midchannel	8	6/20	1700	3.7	17	5.6	4.5	3.3	
128.2	right bank	3	6/21	1100	7.4	17	3.0	8.9	9.8	
125.0	midchannel	2	6/21	1300	4.4	--	6.5	4.4	4.8	
121.5	midchannel	5	6/21	1600	3.1	20	7.2	3.1	11.0	
118.5	midchannel	2.5	6/22	0945	2.3	24	4.4	1.8	13.0	
115.3	midchannel	10	6/22	1300	1.8	25	2.0	1.3	6.0	
112.8	midchannel	10	6/22	1500	2.2	--	5.0	2.2	11.0	
109.9	midchannel	1.5	6/22	1600	4.6	23	6.8	3.8	7.2	

[1] Temperature Correction

$$B_{20} = B_T (1.065)$$

TABLE D-2

BENTHIC OXYGEN DEMAND OF THE

HOLSTON RIVER BELOW KINGSPORT, TENNESSEE

TVA DATA

Mile	Horizontal Location	Water Depth ft.	Date	Time EDT	Rate at Temp. and DO gm/m²-day	°C	mg/1	Rate[1/] at 20°C gm/m²-day	COD of Sediment gm/kg	Volatile Solids percent	Remarks
141.1	Midstream by island	1.5	6-24-69	0940	13.0	21.1	4	12.1	--	--	By railroad bridge pier at confluence
141.0	10 feet from left bank	1.0	7-27-69	1125	2.93	26.5	0.5	1.95	34	7.9	Sand
138.3	25 t right of lower Clay Island	5.0	6-24-69	1120	11.5	21.4	3.6	10.5	--	--	
138.3	25 feet right of lower Clay Island	3.0	7-27-69	1255	15.8	27.0	2.0	10.16	93	15.4	
134.0	20 feet from left bank	3.0	6-20-69	1250	9.95	17.0	6.6	12.0	--	--	
134.0	10 feet from right bank	2.0	7-27-69	1536	2.54	29.0	5.1	1.44	22	4.9	Sand
128.2	30 feet from right bank	4.0	6-21-69	1110	7.25	17.1	4.0	8.70	--	--	
128.2	3 feet from right bank	1.0	7-28-69	0932	11.13	27.2	2.15	7.07	43	10.1	
124.2	3 feet from right bank	3.0	7-30-69	1015	8.93	25.0	1.53	6.51	--	--	
118.8	20 feet from left bank	4.0	6-21-69	1725	5.39	20.1	9.8	5.36	--	--	
118.8	20 feet from left bank	2.0	7-28-69	1230	3.61	28.0	7.8	2.18	7	2.7	Sand
115.3	30 feet from left bank	4.0	6-22-69	1310	4.61	24.0	2.3	3.59	--	--	
115.3	20 feet from left bank	6.0	7-28-69	1445	4.49	27.2	4.80	2.85	99	13.2	Behind railroad bridge pier
109.9	100 feet from left bank	4.0	6-22-69	1500	6.55	21.8	5.9	5.84	--	--	
109.9	50 feet from left bank	4.0	7-28-69	1638	22.25	26.2	7.55	15.08[2/]	115	14.3	Sediment roiled

[1/] $B_{20} = B_T [k,065]^{(20-T)}$

[2/] Unrepresentative because of sediment disturbance.

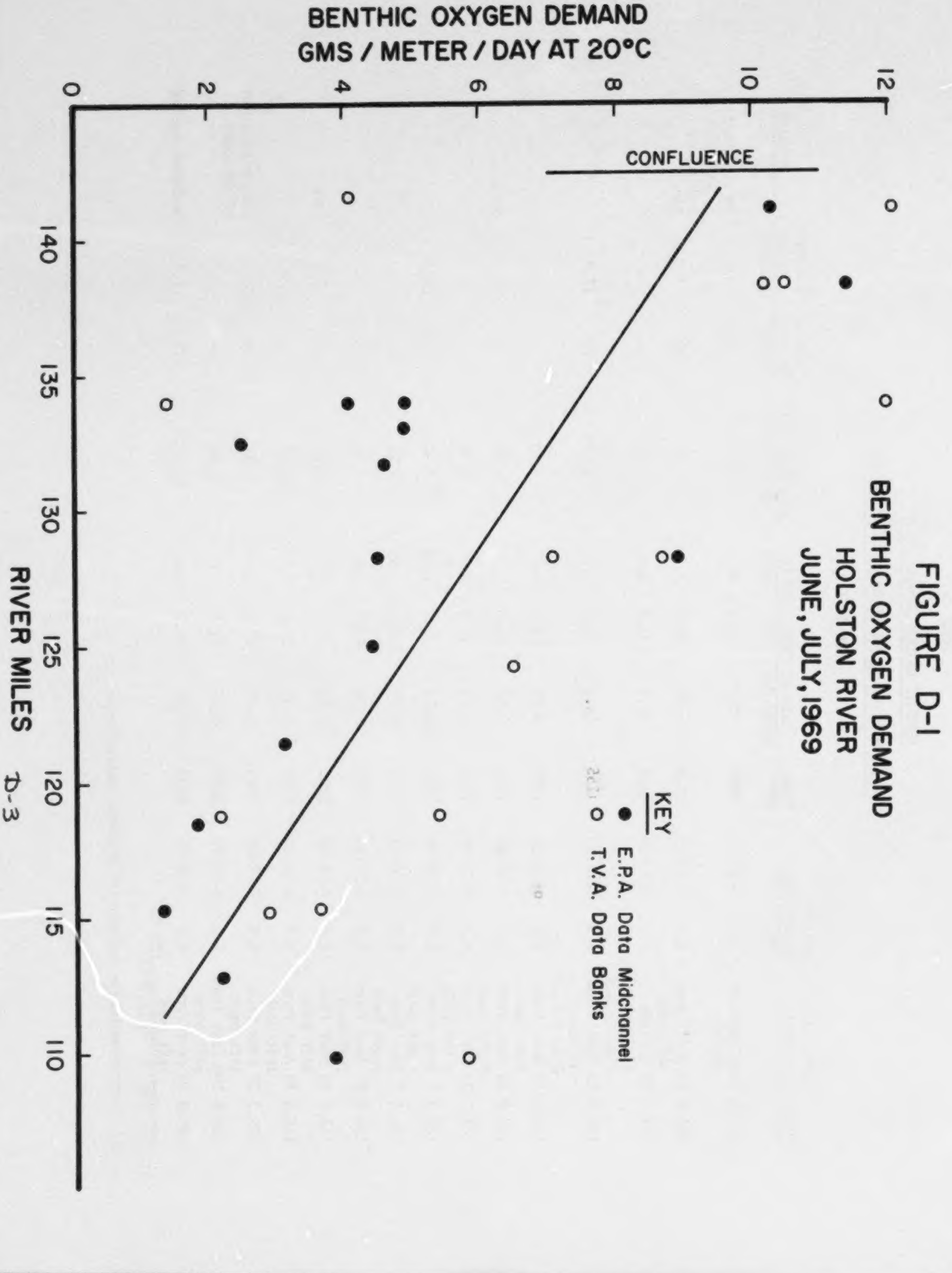


FIGURE D-I
BENTHIC OXYGEN DEMAND
HOLSTON RIVER
JUNE, JULY, 1969

Appendix E

BIOLOGICAL STANDING CROP

A. Discussion

An assessment of the vegetative standing crop in a portion of the Holston River was made in June and July 1969. These studies included the determination of the phytoplankton population and an estimate of the density of benthic algae and vascular aquatic plants. The purpose was to determine the relative abundance of aquatic vegetation and its relationship to certain natural factors and industrial pollutants. To study the biological changes due to pollution, it was necessary to recognize first the effect of natural factors on the river and its flora. A study was made of the stream character including the bottom materials and the contour of portions of the river bottom.

The growth of aquatic plants in the Holston River was luxuriant and comprised of seven species. Only two of these species were algae (*Cladophora* and *Hydrodictyon*), the others were vascular plants (*Heteranthera dubia*; *Potamogeton pectinatus*; *P. nodosus*; *P. crispus*; and *Vallisneria americana*). Species composition changed from one river section to another. Composition data are shown, with ash-free dry weights and certain physical features, for each sampling site of the June and July study in Appendix A and B, respectively.

Colored aerial photographs showed the vegetation had three readily discernible shades of green. The dark-green color was recorded over a total length of 10.9 river miles, while medium- and light-green colors were recorded over 10.8 and 10.5 river mile lengths, respectively.

Comparison of this photographic information with ground data indicated: (1) a dark-green color equaled an average vegetative density value (organic dry weight) of 3.7 gm/ft^2 (2) medium-green equaled 2.5 gm/ft^2, and (3) light-green equaled 0.4 gm/ft^2. From these data an estimated standing crop of 170 tons organic dry (ash free) weight was calculated in the study area in June 1969.

Phytoplankton population at seven river locations varied from 330 to 3,300 organisms per milliliter during the two studies. Coccoid green algae and diatoms were the dominant forms collected.

Determination of standing crop in a 32-mile stretch of river presents numerous problems. A distinction is necessary between standing crop and biomass. Both include the weight of plant material, but biomass includes all parts of all plants. This study is limited to the weight of the green material in certain plants and is therefore a standing crop study.

In this report the standing crop is expressed in terms of organic dry (ash-free) weight instead of fresh weight. Water content (the majority of the fresh weight) varies greatly among species, depending upon seasonal stages of development and environment conditions and there is little relationship between fresh weight and organic matter. Determination of the organic dry weight by substraction of the ash weight is considered the most straightforward method of quantifying plant material.

Organic dry weight data, certain physical and biological parameters and aerial photographic information were used to estimate the June 1969 standing crop of 170 tons from river mile 141.2 to 109.9.

The July study was less intense. It did not include aerial photography or as many ground true studies as the June survey. At best, a comparison of the June and July data show two trends; (1) a similar distribution of aquatic vegetation and (2) an increased floral standing crop in the Holston River during the one-month period.

Aerial photography was useful in determining the relative density of vegetation in the study area. Figure E-1 shows that three areas contained the most dense vegetative growth: from mile 128.7 to 130.6, from 113.9 to 134.0, and from 137.4 to 138.8. Plant types could not be distinguished from photographic information. A biological assessment of the crop components is understood best by observing ecological conditions as one travels downstream by boat.

The Holston River from mile 141.2 to 109.9 had an average depth of 4.0 to 4.5 feet during the June and July survey, respectively. The irregular bottom formed numerous shallow riffle areas. Eight of these areas were considered extensive because they nearly transected the river and extended downstream 100 feet or more. Crevices in these rock-bottom riffles were filled with sand, clay, and silt. This provided sufficient substrate for the root systems of vascular plants.

Shallow areas from mile 141.2 to 135.4 were carpeted with a floral community of sago pondweed (Potamogeton pectinatus) and floating-leaf pondweed (Potamogeton nodosus). At mile 135.4 silt deposition in rock crevices appeared to increase. The curly-leaf

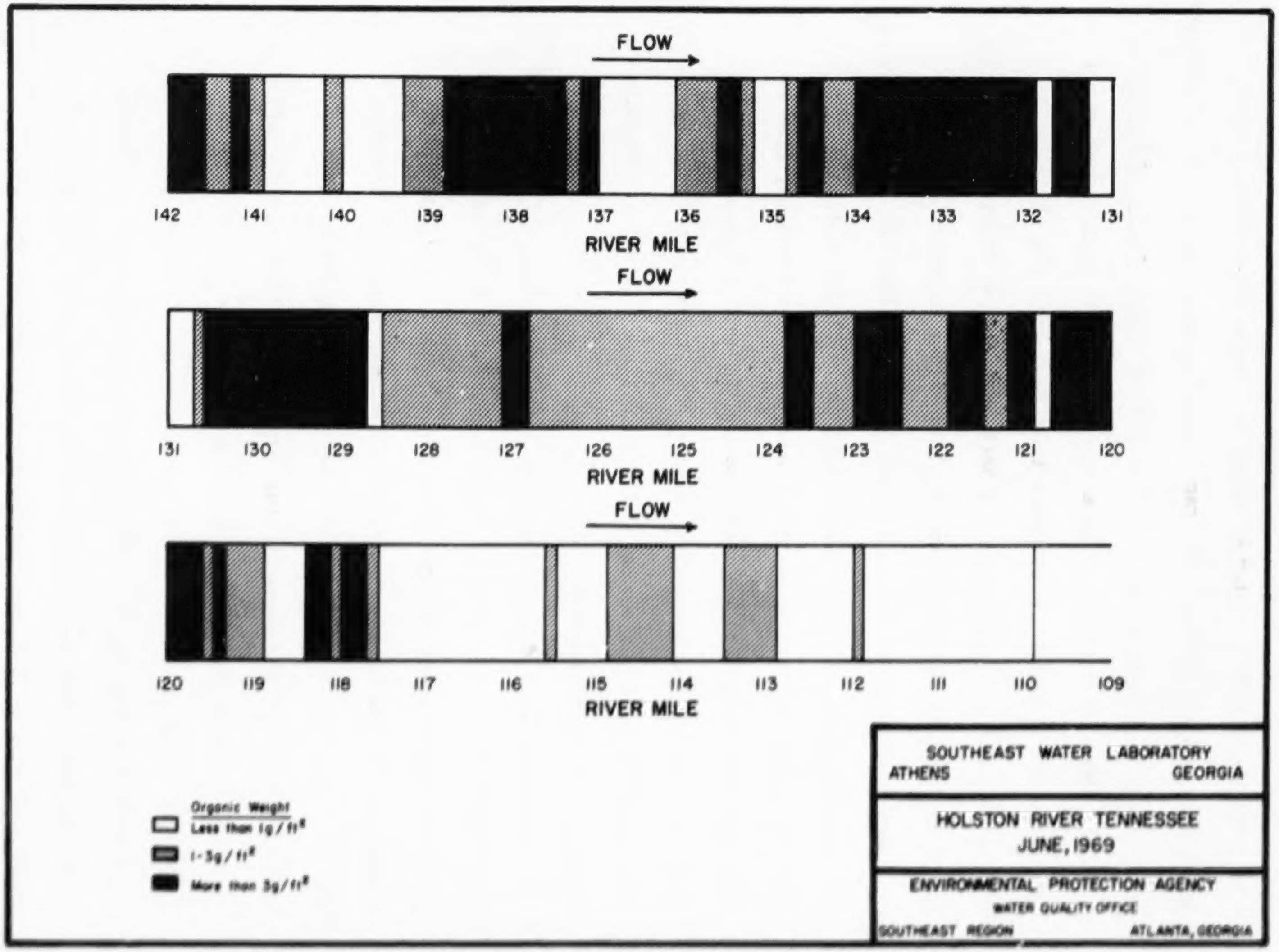


FIGURE E-1 Three Diagrammatic Reaches of the Holston River Showing the Relative Density, Extent and Location of Benthic Flora pondweed (*P. crispus*) was observed in association with the other two types of pondweeds. Farther downstream at mile 120.4 the plant community in shallows changed markedly. Pondweed dominance was replaced by beds of water stargrass (*Heteranthera dubia*). A filamentous green algae (*Cladophora sp*) and wild celery (*Vallisneria americana*) were also much in evidence. These plant community changes reflected environmental changes. Pond-weeds that dominated the shallows from mile 141.2 to 120.4 prefer a hard or brackish water environment, while the downstream plants are more sensitive to salt water.

Water velocity as well as water depth is important in determining the type of flora present. Generally, the velocity upstream from mile 120.4 was swifter than downstream. Sago pondweed may have been dominant because its streamlined, filamentous leaves made the plant more suited to the swifter water. As water velocity slowed near mile 120.4, other broad-leafed plants such as water star-grass replaced the sago pondweed.

Eleven areas had depths greater than seven feet. These areas were considered pools because light penetration below seven feet appeared insufficient for vascular plant growth. Silt and clay deposition in the pool areas increased downstream. For example, the pool area at mile 140.9 had a deposit of less than 0.3 feet, while at mile 110 the deposit near one shoreline was approximately three feet thick. Marginal vegetation along these pools included pondweeds, wild celery, filamentous algae, and floating patches of duckweed (*Lemna minor*). Broken plant filaments were collected from the pools, but no living vascular plants were observed. The filaments were washed into the pools from upstream shallows.

River plankton populations varied from section to section during the two surveys. Densities were generally low and no trend toward an algal bloom was observed.

B. Biological Procedures

Sampling stations were located on a 32.2 mile stretch of the Holston River from mile 141.2 to 109.9. Fourteen stations were established, each coinciding with a chemical study site shown on the map of Figure 1. In June the entire study area was floated by boat, and biological material was collected from the 14 stations. In July the river was floated again to assess floral changes, and material was collected from three stations. A total of 108 vegetative samples for standing crop analyses and 14 water samples for phytoplankton analysis were collected during the two surveys.

Each station from which samples of flora were collected consisted of a river cross-section. The approximate river width was determined using a nylon rope calibrated in feet. The rope was fastened to a tree trunk on one shoreline, stretched across the stream and fastened on the opposite shoreline. Water depth and the river bottom contour were determined along this rope line using a boat-mounted recording fathometer. At six evenly spaced intervals along the rope, benthic flora and substrate were collected with an Orange-peel bucket-sampler. Vegetation and sediment were separated. Sediment nonmenclature based upon the approximate percentage of silt, sand, clay, gravel and rock was assigned and recorded for each sample. Vegetation was placed in plastic bags, labeled and refrigerated in an ice chest.

At seven stations, a two-liter water sample was collecteed for phytoplankton analysis. The samples were taken from mid-stream at a one-foot depth and preserved by adding enough formalin to effect a 5 percent solution.

Vegetation was identified to species and the green plant material of vascular plants was separated from its root system and ash-free dry weight was determined for the green material. For phytoplankton, analytical procedures followed the methods described by Weber (1966).

In addition to the ground true studies, aerial photographs of the river were taken in June 1969. This observation technique enabled the charting of the relative location and extent of aquatic weed beds. Photographic information was compared with ground true data to determine the concomitant variables. These data were used to estimate the standing crop for the entire study area.

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

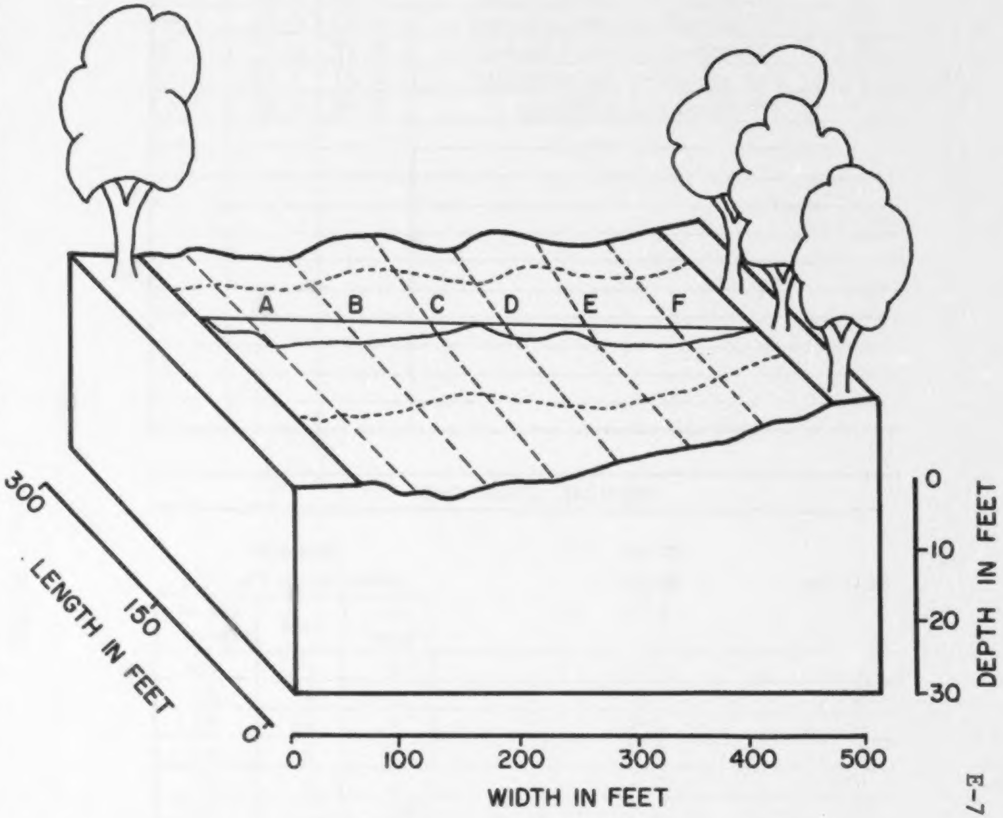
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Potamogeton pectinatus	28.20	2.03	7.86
B	Potamogeton pectinatus	9.06	4.71	4.35
C	Potamogeton pectinatus	5.72	Broken	
D	Potamogeton pectinatus	0.40	0.14	0.25
E	Potamogeton pectinatus	9.00	6.42	2.58
F	Potamogeton pectinatus	11.25	7.30	3.95

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	3.0	5	5	90
B	2.8	5	5	90
C	1.4	20	5	75
D	1.6	20	5	75
E	2.0	5	5	10
F	1.9	5	5	90

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 141.2


A
B
C
D
E
F
300
150
0
LENGTH IN FEET
0
100
200
300
400
500
WIDTH IN FEET
0
10
20
30
DEPTH IN FEET

E-7

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

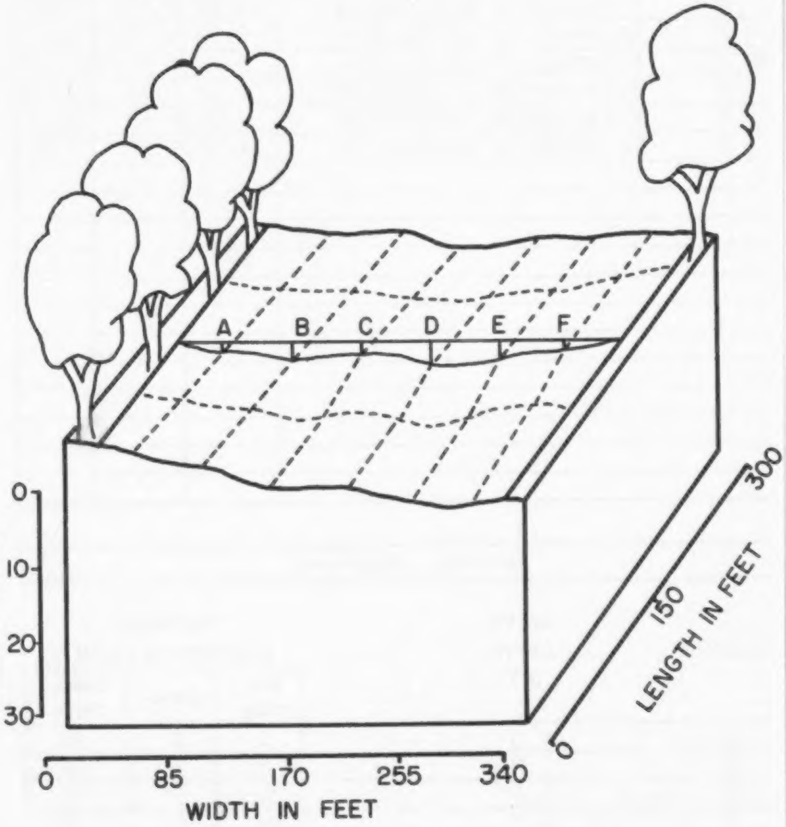
STATIONS	SPECIES	WEIGHT (g/ft^2)* Dry	Ash	Org dry
A	No Vegetation			
B	Potamogeton pectinatus	31.07	7.85	23.22
C	Potamogeton pectinatus	1.98	1.64	0.34
D	Potamogeton pectinatus	1.81	0.74	1.06
E	Potamogeton pectinatus	9.97	4.97	5.00
F	Potamogeton pectinatus	4.27	3.14	1.13
	Potamogeton nodosus	4.08	1.95	2.13

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2) Silt Clay	Sand	Gravel Rock
A	1.0	5	15	80
B	2.1	5	15	80
C	1.9	5	10	85
D	3.5	5	5	90
E	3.1	5	5	90
F	0.9	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE
137.8



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

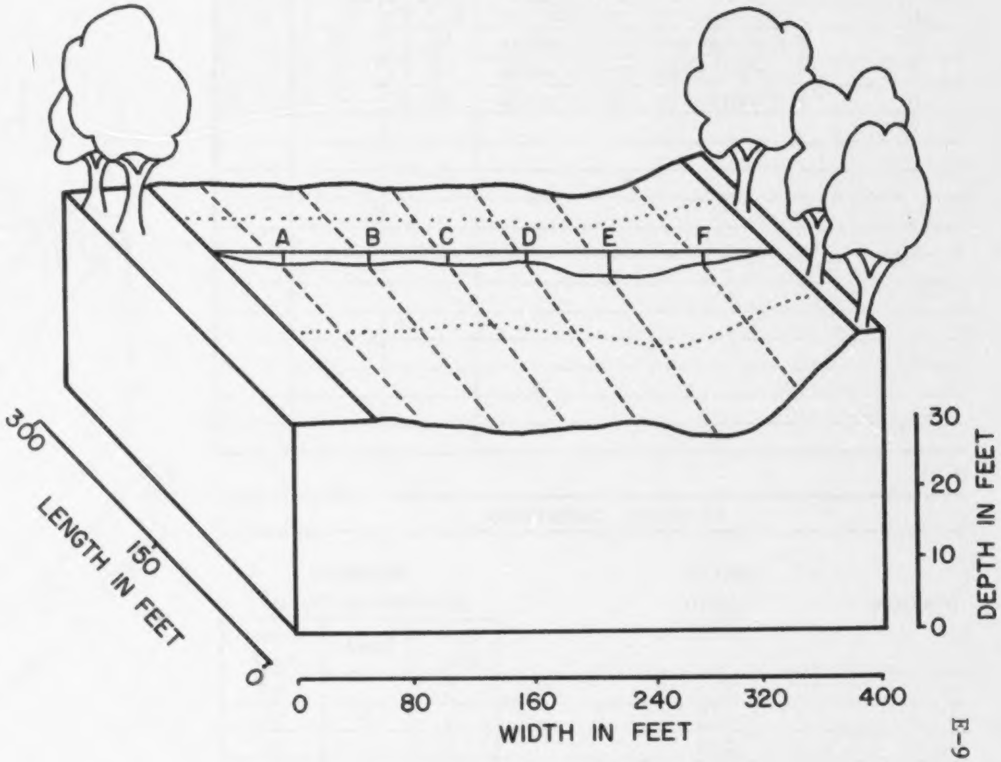
STATIONS	SPECIES	WEIGHT (g/ft^2)*		
		Dry	Ash	Org dry
A	Potamogeton pectinatus	24.63	17.18	7.45
B	Potamogeton pectinatus	21.65	13.02	8.64
C	Potamogeton pectinatus	14.09	10.97	3.12
D	Potamogeton pectinatus	4.30	2.56	1.74
E	Potamogeton pectinatus	18.52	11.24	7.28
F	Potamogeton pectinatus	15.50	11.66	3.84

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2)		
		Silt Clay	Sand	Gravel Rock
A	2.0	15	5	90
B	2.2	5	5	90
C	2.0	5	5	90
D	2.1	5	5	90
E	3.2	5	5	90
F	1.9	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 135.4


A
B
C
D
E
F
300
150
0
LENGTH IN FEET
0
80
160
240
320
400
WIDTH IN FEET
30
20
10
0
DEPTH IN FEET

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (July, 1969)

STANDING CROP

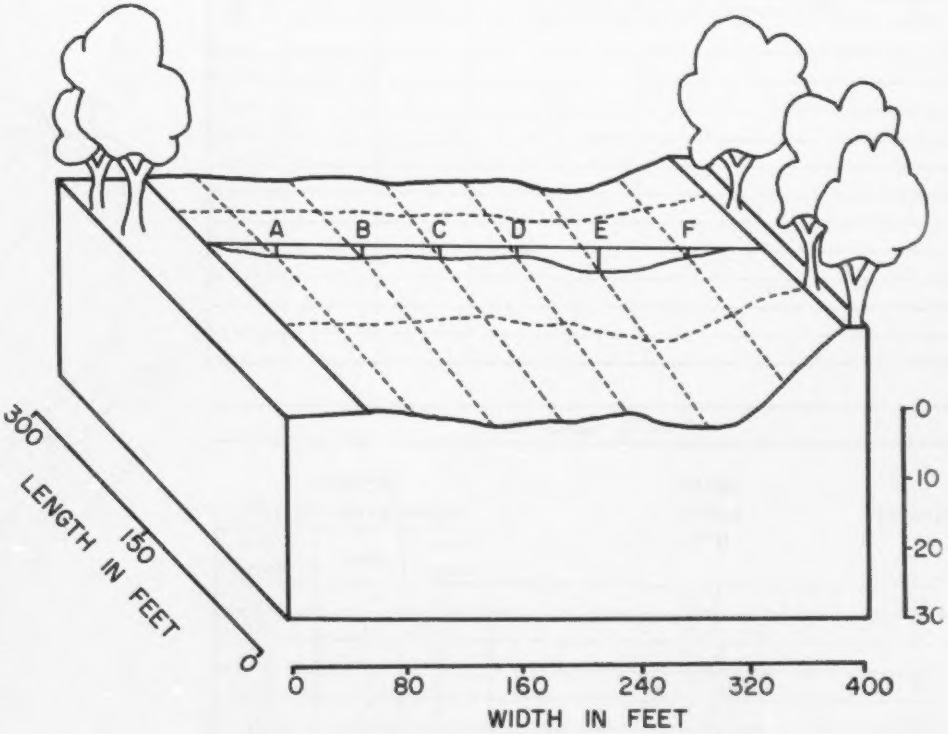
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Potamogeton pectinatus	17.89	11.04	6.85
B	Potamogeton pectinatus	68.03	48.48	19.56
C	Potamogeton pectinatus	133.85	97.11	36.74
D	Potamogeton pectinatus	40.97	28.59	12.38
E	Potamogeton pectinatus	48.12	26.52	21.61
F	Potamogeton pectinatus	86.83	56.93	29.90

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	2.2	5	5	90
B	2.3	5	5	90
C	2.0	5	5	90
D	2.2	5	5	90
E	3.5	5	5	90
F	2.0	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 135.4



E-10

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

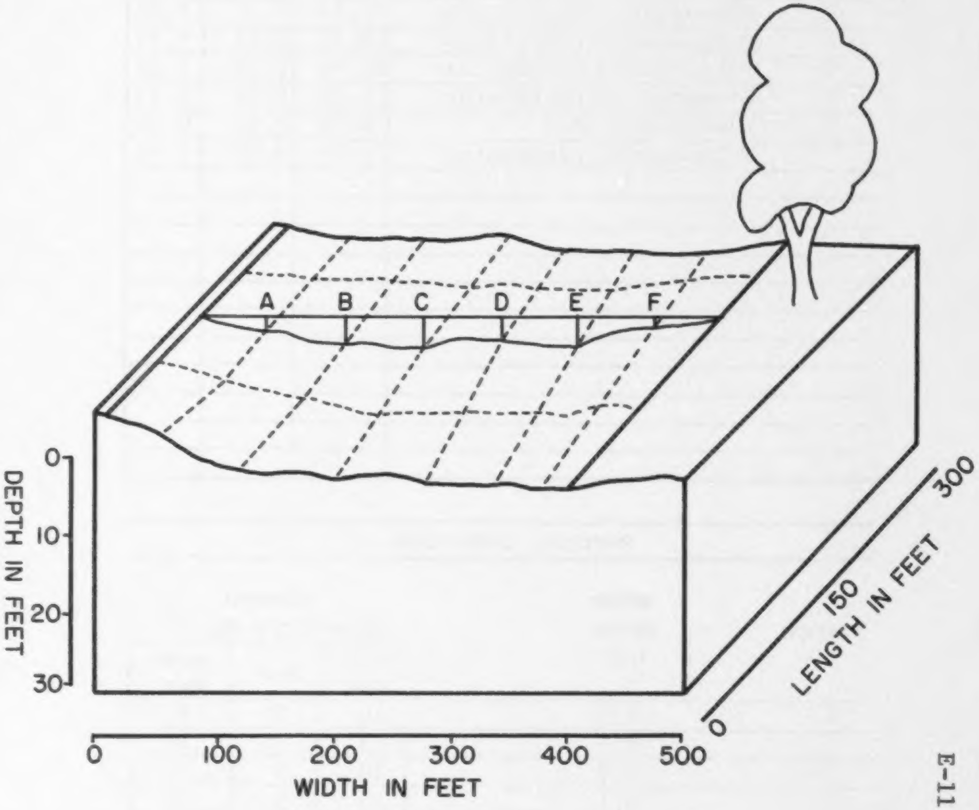
STATIONS	SPECIES	WEIGHT (g/ft^2)*		
		Dry	Ash	Org dry
A	Potamogeton pectinatus	10.52	7.27	3.25
B	Potamogeton pectinatus	22.48	13.07	9.41
C	Potamogeton pectinatus	0.66	0.18	0.48
	Cladophora	0.67	0.55	0.11
D	Potamogeton pectinatus	2.68	0.73	1.96
E	Potamogeton pectinatus	2.14	0.60	1.54
	Potamogeton Nodosus	1.06	0.24	0.81
F	Potamogeton pectinatus	6.44	1.36	5.08

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2)		
		Silt Clay	Sand	Gravel Rock
A	2.2	10	5	85
B	4.8	5	5	90
C	4.5	5	5	90
D	3.1	5	5	90
E	4.0	5	5	90
F	2.1	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 131.4



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

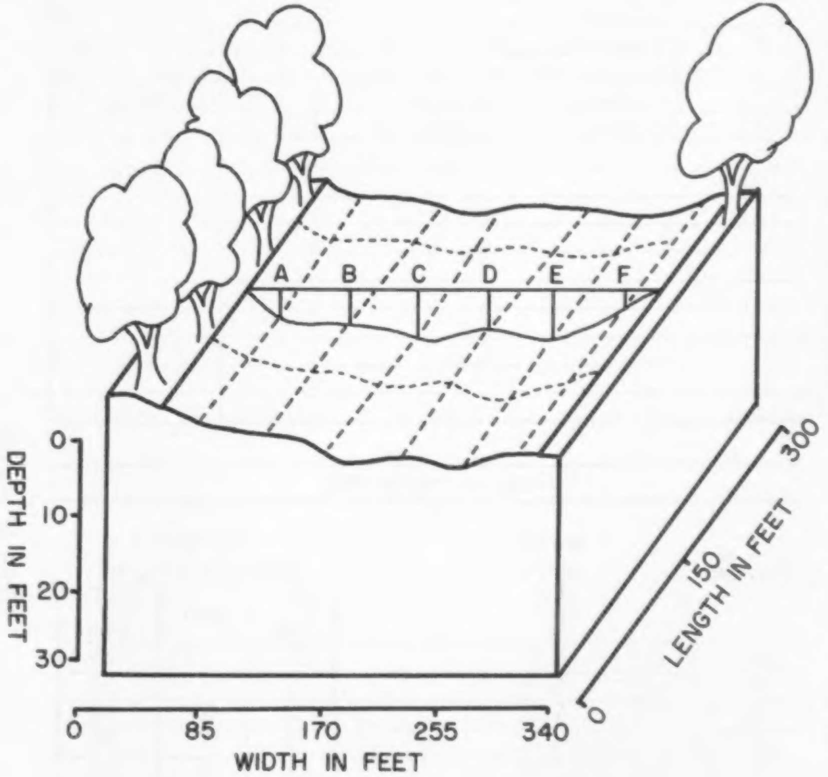
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Potamogeton pectinatus	0.85	0.58	0.27
B	Potamogeton pectinatus	9.97	6.17	3.80
C	Potamogeton pectinatus	12.10	5.11	6.99
D	Potamogeton pectinatus	10.94	6.08	5.86
E	Potamogeton pectinatus	1.03	0.31	0.72
F	Cladophora sp.	0.36	0.22	0.14
	Potamogeton pectinatus	1.96	0.55	1.41

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	5.2	10	5	85
B	5.0	15	5	80
C	6.8	20	5	75
D	6.1	5	5	90
E	7.1	10	10	80
F	4.3	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 129.7



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

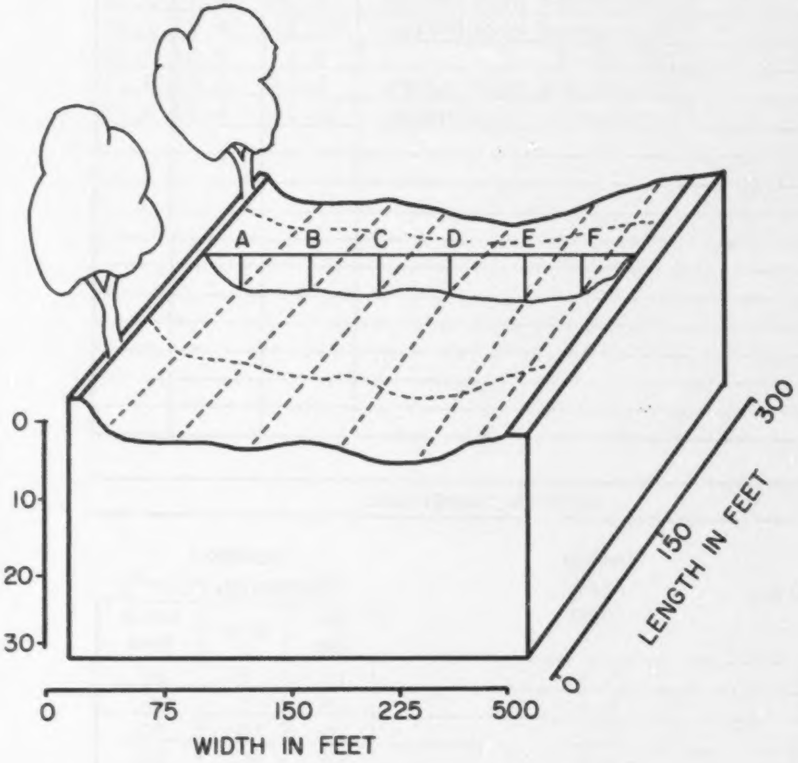
STATIONS	SPECIES	WEIGHT (g/ft^2)* Dry	Ash	Org dry
A	No Vegetation			
B	Potamogeton pectinatus	15.50	9.01	6.49
C	Potamogeton pectinatus	34.85	23.70	11.1
D	Potamogeton pectinatus	13.29	7.59	5.70
E	Cladophora sp.	0.80	0.61	0.19
	Potamogeton pectinatus	2.46	1.03	1.43
F	Cladophora sp.	0.32	0.18	0.15

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2) Silt Clay	Sand	Gravel Rock
A	5.7	15	5	80
B	5.6	10	5	85
C	6.0	10	10	80
D	5.9	10	10	80
E	7.2	10	5	85
F	6.4	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 128.3



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (July, 1969)

STANDING CROP

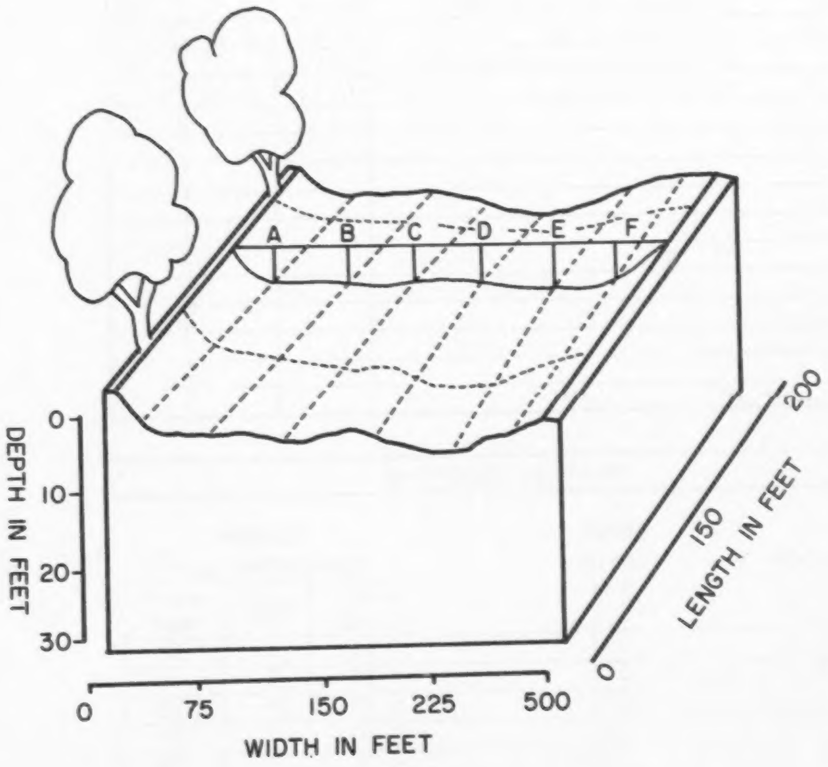
STATIONS	SPECIES	WEIGHT (g/ft^2)* Dry	Ash	Org dry
A	No vegetation			
B	Potamogeton pectinatus	54.40	39.71	14.70
C	Potamogeton pectinatus	36.36	24.18	12.18
D	Potamogeton pectinatus	41.85	34.25	7.60
E	Cladophora	0.15	0.05	0.10
	Potamogeton pectinatus	0.28	0.86	0.19
F	Potamogeton pectinatus	10.28	4.53	5.76

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2) Silt Clay	Sand	Gravel Rock
A	5.9	15	5	80
B	5.5	10	5	85
C	6.1	10	10	80
D	6.0	10	10	80
E	7.1	10	5	85
F	6.5	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 128.3



E-14

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

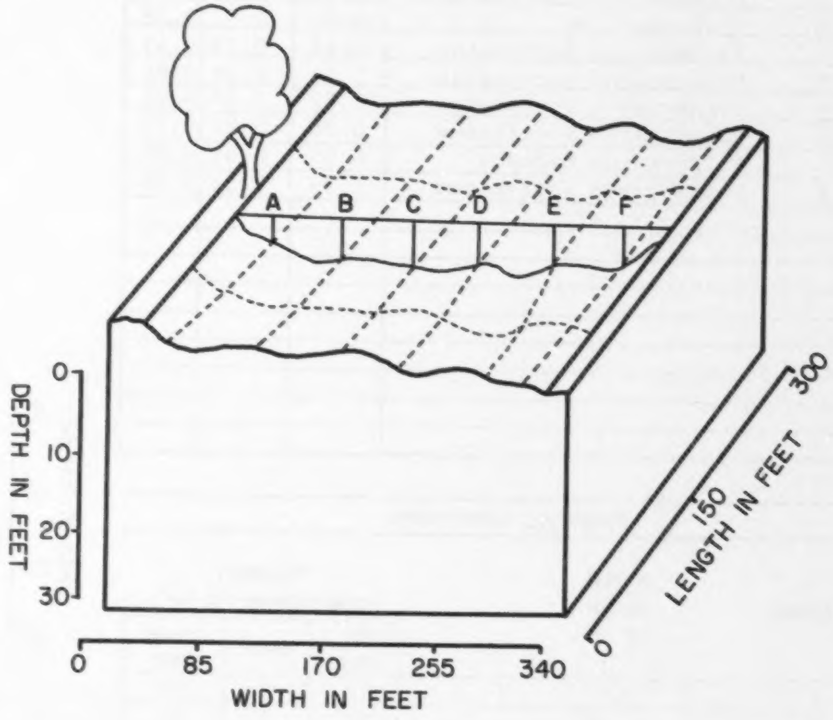
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Potamogeton	0.11	0.07	0.04
B	Cladophora sp.	0.14	0.06	0.08
C	Cladophora sp.	0.01	0.00	0.01
D	Cladophora sp.	0.52	0.38	0.14
E	Potamogeton crispus	0.17	0.04	0.14
	Cladophora	0.01	0.00	0.01
	Potamogeton pectinatus	2.83	0.66	2.17
F	Cladophora	4.38	3.51	0.88

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	3.9	90	5	5
B	6.1	10	5	85
C	7.2	10	5	85
D	6.0	5	5	90
E	6.4	15	5	80
F	7.0	10	5	85

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 124.2


A
B
C
D
E
F
DEPTH IN FEET
0
10
20
30
0
85
170
255
340
WIDTH IN FEET
0
150
300
LENGTH IN FEET

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

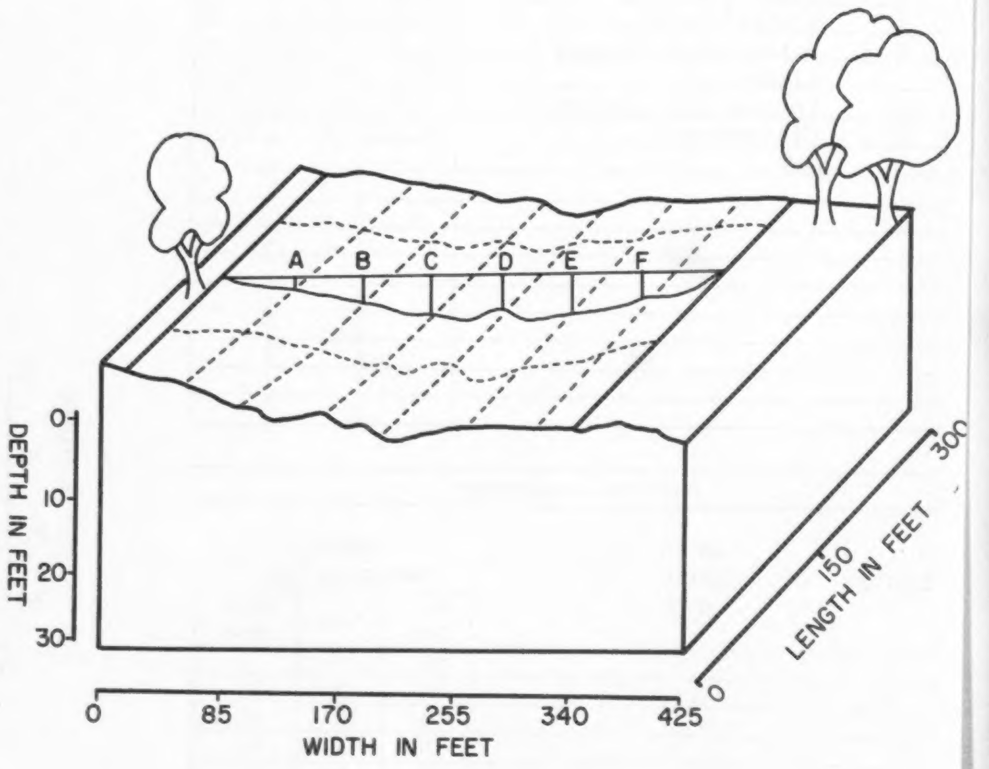
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Cladophora sp.	6.31	4.91	1.40
	Potamogeton pectinatus	0.35	0.23	0.12
B	Cladophora sp.	0.84	0.47	0.38
	Potamogeton pectinatus	0.91	0.29	0.63
C	Potamogeton pectinatus	5.17	2.12	3.05
D	Potamogeton pectinatus	11.32	7.07	4.25
E	Potamogeton pectinatus	0.96	0.23	0.73
	Potamogeton nedosus	0.05	0.01	0.04
F	Potamogeton pectinatus	1.54	0.56	0.98

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	1.9	10	10	80
B	4.2	10	5	85
C	5.6	10	5	85
D	5.4	10	10	80
E	6.8	5	15	80
F	4.7	15	10	75

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 122.8



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

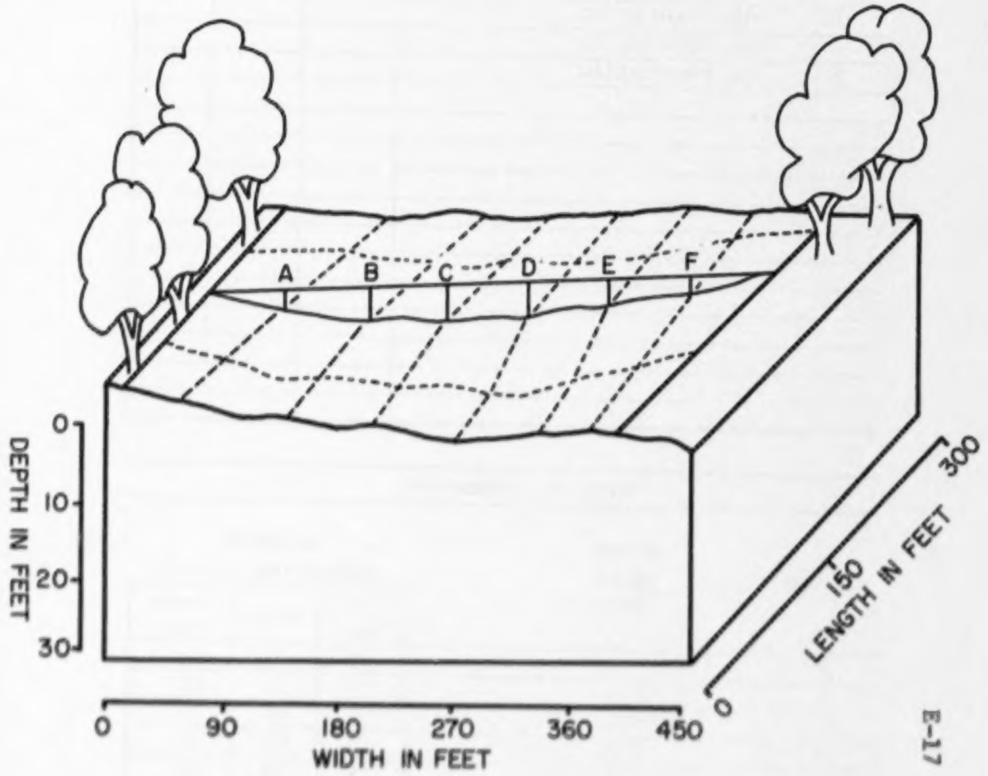
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Potamogeton crispus	2.79	1.25	1.54
	Cladophera sp.	0.14	0.05	0.09
B	Vallisneria americana	0.06	0.03	0.04
	Cladophora sp.	2.71	2.20	0.52
C	Potamogeton pectinatus	6.29	1.17	5.12
	Potamogeton nodosus	0.57	0.46	0.11
	Cladophora sp.	0.37	0.18	0.19
D	Cladophora sp.	3.37	2.98	0.39
E	Potamogeton nodosus	2.43	0.85	1.58
	Potamogeton pectinatus	1.52	0.70	0.53
	Cladophora sp.	0.03	0.01	0.02
F	no vegetation			

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	2.8	15	5	80
B	5.3	5	5	90
C	5.5	10	5	85
D	5.4	10	10	80
E	4.0	15	10	75
F	3.5	15	30	55

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 120.4



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

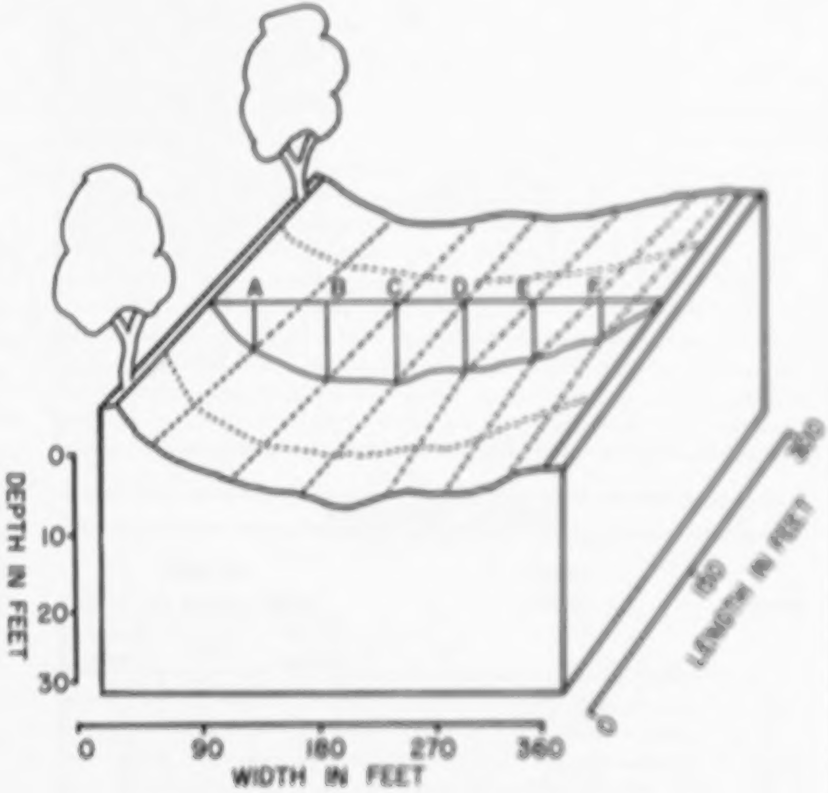
STATIONS	SPECIES	WEIGHT (g/ft²)*		
		Dry	Ash	Org dry
A	no vegetation			
B	no vegetation			
C	no vegetation			
D	no vegetation			
E	no vegetation			
F	no vegetation			

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²)		
		Silt Clay	Sand	Gravel Rock
A	6.8	30	5	65
B	10.4	25	10	65
C	10.6	20	20	60
D	9.3	20	10	70
E	8.6	25	10	65
F	6.0	40	20	40

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 118.4


A
B
C
D
E
F
DEPTH IN FEET
0
10
20
30
0
90
180
270
360
WIDTH IN FEET
0
150
300
LENGTH IN FEET

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

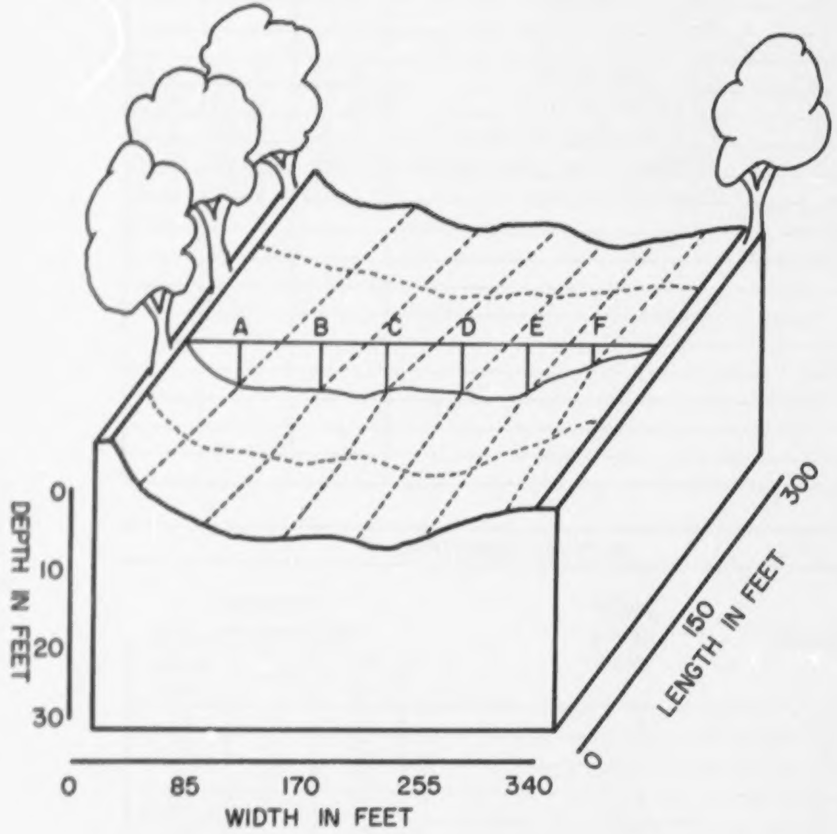
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	no vegetation			
B	Cladophora sp.	0.48	0.29	0.19
C	Cladophora sp.	1.74	1.44	0.31
D	Cladophora sp.	5.05	3.95	1.10
E	Cladophora sp.	0.44	0.30	0.13
F	no vegetation			

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	5.8	40	10	50
B	6.9	10	10	80
C	6.7	10	10	80
D	6.8	10	10	80
E	6.9	10	10	80
F	3.6	30	10	60

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 117.0


A
B
C
D
E
F
DEPTH IN FEET
0
10
20
30
0
85
170
255
340
WIDTH IN FEET
0
150
300
LENGTH IN FEET

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

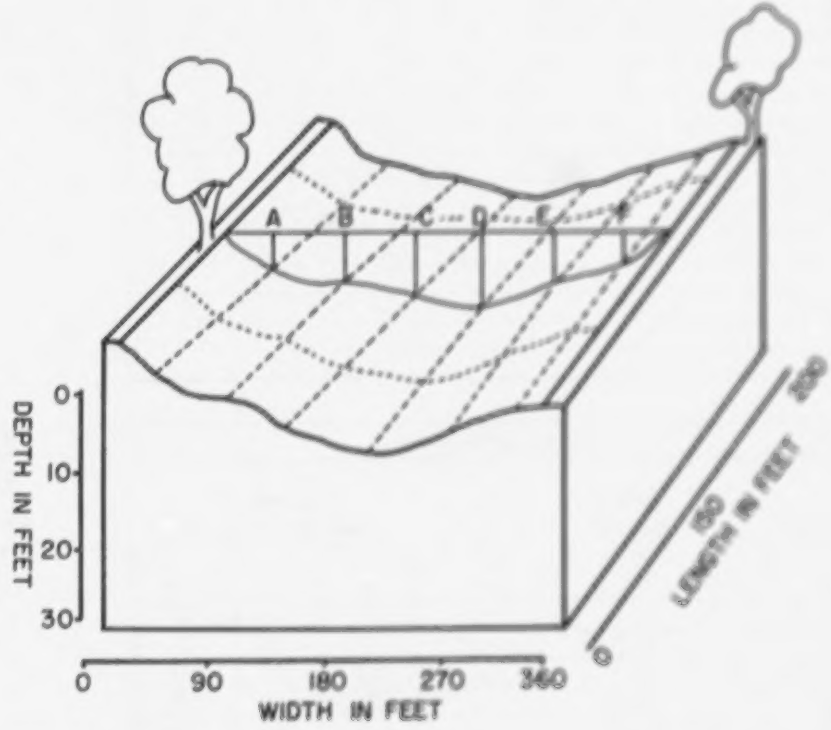
STATIONS	SPECIES	WEIGHT (g/ft^2)* Dry	Ash	Org dry
A	no vegetation			
B	no vegetation			
C	no vegetation			
D	Cladophora sp.	0.25	0.23	0.03
E	Cladophora sp.	0.74	0.59	0.15
F	Potamogeton crispus	1.70	0.56	1.14
	Potamogeton pectinatus	10.94	6.08	4.86
	Cladophora sp.	0.15	0.08	0.07

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft^2) Silt Clay	Sand	Gravel Rock
A	5.4	30	5	65
B	7.3	40	10	50
C	8.5	30	20	50
D	9.6	30	10	60
E	7.0	25	10	65
F	5.5	35	10	55

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic-dry weight (ash-free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 115.3


A
B
C
D
E
F
DEPTH IN FEET
0
10
20
30
0
90
180
270
360
WIDTH IN FEET
0
150
200
LENGTH IN FEET

E-20

STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June ,1969)

STANDING CROP

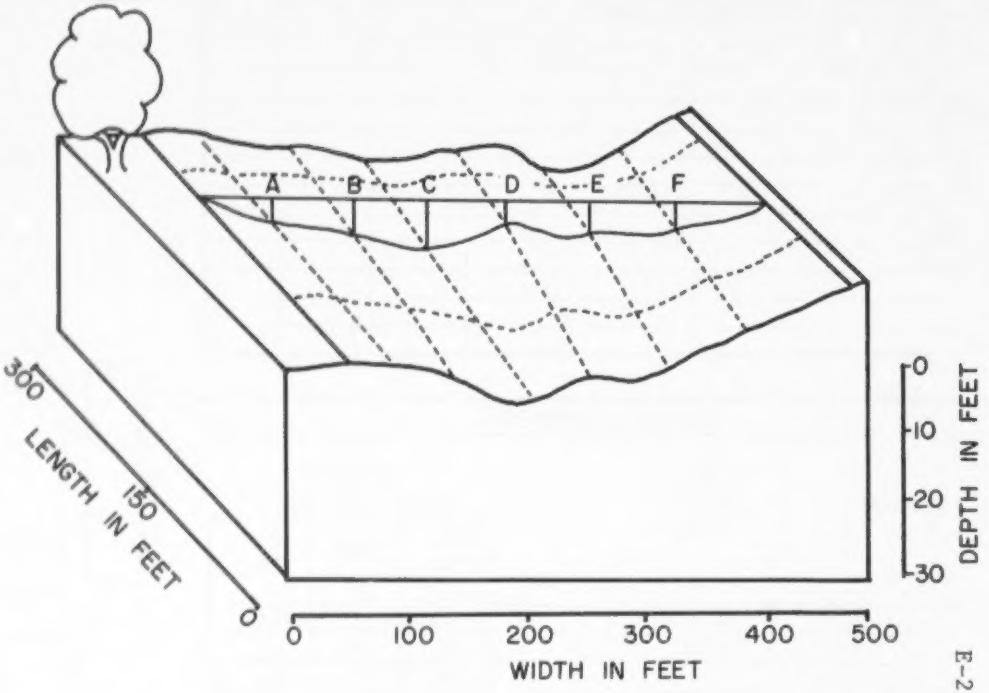
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Heteranthera dubia	1.88	1.00	0.88
B	Heteranthera dubia	1.36	8.72	4.91
	Cladophora sp.	0.67	0.57	0.09
C	Heteranthera dubia	0.22	0.07	0.15
	Cladophora sp.	0.68	0.43	0.25
D	Potamogeton pectinatus	0.25	0.10	0.15
	Vallisneria americana	2.70	1.52	1.18
E	Heterantheria dubia	5.34	1.62	3.72
	Cladophora sp.	0.16	0.07	0.09
	Potamogeton pectinatus	10.75	8.50	2.25
F	Heteranthera dubia	1.77	0.46	1.31
	Potamogeton pectinatus	1.19	0.37	0.82

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	2.5	10	30	60
B	4.6	20	10	70
C	6.8	10	10	80
D	2.8	10	15	75
E	4.0	10	10	80
F	3.2	10	10	80

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 113.3



STANDING CROP OF BENTHIC FLORA AND PHYSICAL FEATURES IN THE HOLSTON RIVER, TENNESSEE (June, 1969)

STANDING CROP

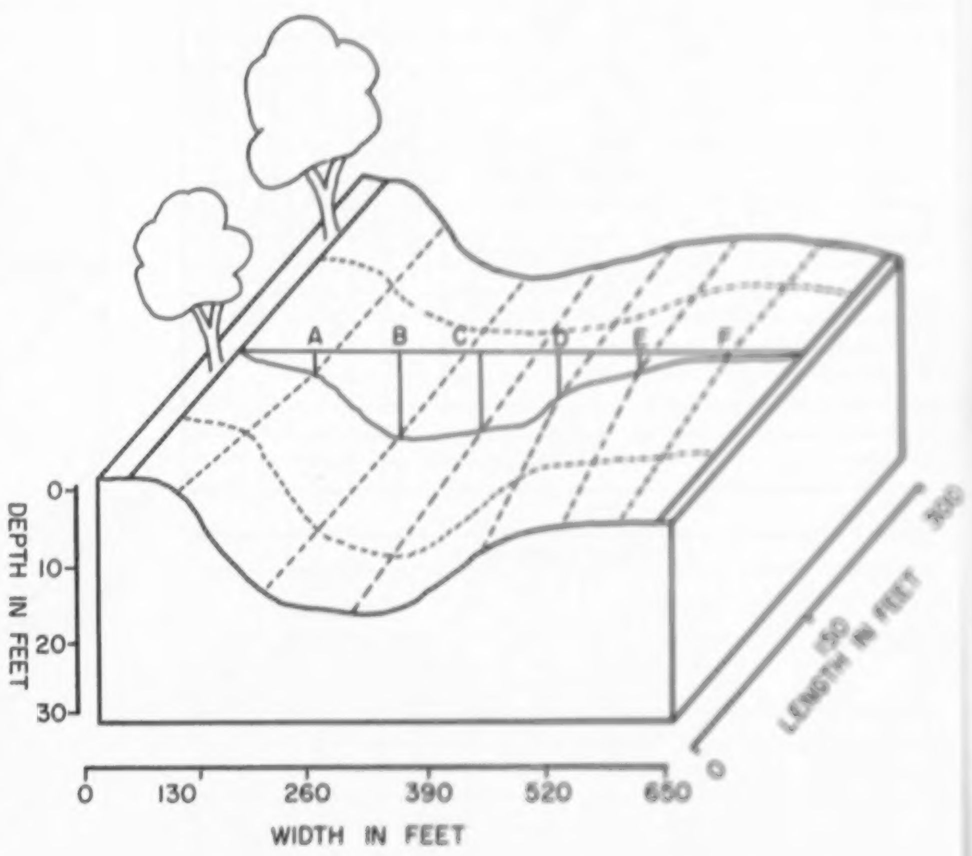
STATIONS	SPECIES	WEIGHT (g/ft²)* Dry	Ash	Org dry
A	Hydrodictyan sp	1.31	0.55	0.76
B	no vegetation			
C	no vegetation			
D	no vegetation			
E	no vegetation			
F	no vegetation			

PHYSICAL CONDITIONS

STATION	WATER DEPTH (FT)	SEDIMENT COMPOSITION (%/ft²) Silt Clay	Sand	Gravel Rock
A	3.0	70	20	10
B	11.2	50	10	40
C	10.9	50	10	40
D	7.6	60	10	30
E	2.8	70	20	10
F	0.5	90	10	--

* Dry Weight at 105°C for 18 hours
Ash weight at 600°C for 1 hour
Organic - dry weight (ash - free weight) is dry weight minus ash weight

DIAGRAMMATIC TRANSECT OF THE HOLSTON RIVER AT MILE 109.9


A
B
C
D
E
F
DEPTH IN FEET
0
10
20
30
0
130
260
390
520
650
WIDTH IN FEET
0
150
300
LENGTH IN FEET

Appendix F

MATHEMATICAL MODEL

A. Basis for calculations

Data collected during the June-July 1969 survey of the Holston River was used to calculate each of the load quantities and reaction coefficients in the integrated Streeter-Phelps equation given under "Stream Simulation" (Equation 2).

The biochemical oxygen demand (BOD) exerted in any interval of time is expressed by the equation:

$$Y_t = L_o \, (1-10^{-k_1 t}) \qquad (3)$$

where Y_t = BOD exerted at time, t

k_1 = rate of deoxygenation in a laboratory bottle

L_o = total or ultimate amount of carbonaceous BOD available for deoxygenation

The five-day BOD, which is commonly reported, is an indication of the total amount of BOD present. Since the total amount of biodegradeable material depletes the oxygen resources of a stream, the "ultimate" BOD is necessary in the solution of equation (2). This predicates a knowledge of the bottle deoxygenation rate (k_1) for each sampling point. If the classical first order reaction (equation 3) is used, an additional two-day BOD permits solution for the k_1 rate by simultaneous equations:

$$Y_2 = L_o \, (1-10^{-2k_1}) \qquad (3a)$$

TABLE F-1

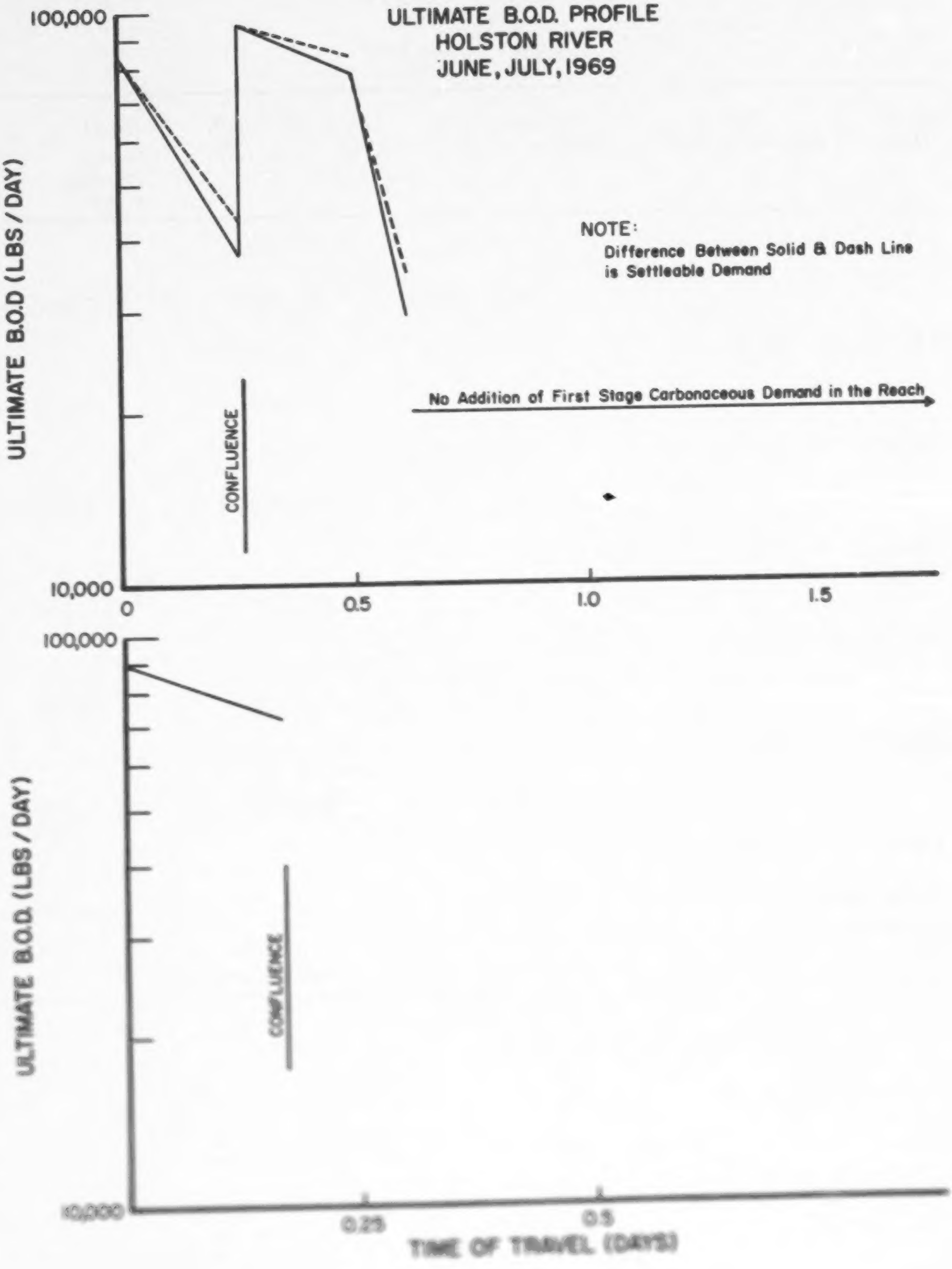
BENTHIC DEMAND

June - July 1969

River Mile	B_o gms/sq m./day	Average B_o gms/sq m./day	Area of Reach sq m. X .25	Total B_o in Reach lbs/day @ 20°C
141.2	11.2			
		10.9	209,000	5,000
137.9	10.5			
		9.7	158,000	3,375
135.4	8.8			
		7.7	222,000	3,765
131.5	6.6			
		6.1	197,000	2,650
128.3	5.6			
		5.1	292,000	3,280
124.3	4.6			
		4.0	382,000	3,360
118.4	3.4			
Background in South Fork	1.5 0.9	1.2	--	85 lbs/day/mi^2

FIGURE F-1

ULTIMATE B.O.D. PROFILE
HOLSTON RIVER
JUNE, JULY, 1969



NOTE:
Difference Between Solid & Dash Line is Settleable Demand

No Addition of First Stage Carbonaceous Demand in the Reach

$$Y_5 = L_o\ (1-10^{-5k_1}) \qquad (3b)$$

This first order equation defining the rate of biochemical oxygen demand, is based upon the assumption that complex hydrocarbon compounds are oxidized to water and CO_2 by biological action. The assumption is further made that no significant nitrification exists in the reaction. Long term BOD analysis of water samples taken from the Holston River below Kingsport showed that, far at least the initial five days, the first order reaction was closely approximated, and that nitrification did not become a significant part of the total reaction initial often the fifth day. The two and five day BOD analyses were used to approximate the ultimate carbonaceous demand, largely excluding the effect of nitrification. Therefore, the term L_o refers only to the carbonaceous portion of the ultimate BOD. The values recorded in Table C-1 were used to calculate L_o.

The benthic demand was observed directly as described in Appendix D. Using the curve shown in Figure D-1 and assuming that 25 percent of the bottom is covered with oxygen demanding material, the benthic demand was converted to pounds per day for each reach as shown in Table F-1. Since the analytical frame work (equation 3) predicates a steady state benthic demand, as much demand must be added each day as is used to maintain this condition. Therefore, the benthic oxygen demand is a function of the settleable carbonaceous BOD.

The amount of ultimate BOD decrease in each reach is the sum of the soluble carbonaceous demand which is satisfied through bio-oxidation and settleable material (B_o) which is deposited. The rate of decrease in soluble material is the river deoxygenation rate (k_r). The river deoxygenation rate is calculated by:

$$k = \frac{\text{Log } L_{o_1} - \text{Log } L_{o_2}}{t} \qquad (4)$$

where L_{o_1} = ultimate carbonaceous BOD at beginning of reach

L_{o_2} = ultimate soluble carbonaceous BOD at end of reach

t = time of travel in the reach

The river model was subdivided at each point below the confluence of the North and South Forks where major waste inputs entered the river. To account for inadequate mixing at points of entry, adjustments were made in identifying values for L_o (ultimate carbonaceous soluble BOD), as follows:

a. At Holston River Mile 1414.2 the L_o values for the North Fork and the South Fork of the river were added.

b. At Holston River Mile 137.9 the L_o value for the North side of the river channel was employed to identify the deoxygenation rate for the upstream reach terminating at this point. Wastes discharged just upstream of Holston River Mile 137.9 were found to have no affect upon BOD observations on the north side of the channel. The total waste volume of the four Holston Army Ammunition Plants (Area B) discharges were assumed to enter immediately below Holston River Mile 137.9, and were added to the L_o value computed for the north side of the channel.

c. A similar convention was observed as in b above in the calculation of l_o values below the Hollister Mills outfall.

d. All other reach L_o values were computed by utilizing mean $BOD_{ultimate}$ observations from one-third points across the river channel.

Nitrogenous oxygen demand (N_o) is a function of the reduction of unsatisfied nitrogenous material (Kjeldahl nitrogen) expressed in terms of oxygen equivalents. The stoichiometric equivalent amount of oxygen necessary to completely oxidize to nitrate one pound of Kjeldahl nitrogen (expressed as N) is 4.57 pounds. However, empirical data have shown that the actual amount may be 4.33 pounds.(1) Therefore, mean Kjeldahl nitrogen values at each sampling location were converted to oxygen equivalents by multiplying by 4.33. The nitrogenous oxidation rate (k_n) was obtained in a similar manner as the carbonaceous BOD oxidation rate (equation 4). Figure F-2 shows the nitrogenous demand profile. Although the twenty-four-hour-effluent sampling indicated that 13,200 pounds per day of Kjeldahl nitrogen as oxygen equivalents was discharged from HAAP Area B, stream data show a considerably greater amount present in the Holston River below the plant. These data were extrapolated back to the outfall to determine the probable river concentration under a completely mixed condition. Concentration of Kjeldahl nitrogen at the outfall location unaffected by the waste discharge is 1.65 mg/l. The concentration at a point

---

(1) Oxygen-Nitrogen Relationships in Auto-trophic Nitrification, Wezernak, C. T., and Gannon, J. J.; Applied Microbiology, September 1967, pp. 1211-1215.

TABLE F-2

SOLUBLE CARBONACEOUS OXYGEN DEMAND

Determination of L_o and k_r

HOLSTON RIVER

June - July 1969

River Mile	L_o (From Y2 and Y5 Data)		B_o Lbs/day		Soluble L_o (adjusted)	t	k_r
	mg/l	lbs/day	20°C	26°C	Lbs/day	days	per day
141.2*	11.3	84,100			84,100		
			5,000	7,300		.263	.78
137.9*	6.3	47,000			54,300		
(HAAP)	--	95,300(1)			--		
			3,375	4,920		.242	.25
135.4	9.6	77,800			82,720		
			3,765	5,490		.167	2.10
131.5	3.6	29,200			34,690		
			2,650	3,860		.210	--(3)
128.3	4.0	32,400			36,260		
			3,280	4,780		.302	--(3)
124.3	--(2)	--(2)			--		
			3,360	4,900		.573	--(3)
118.4	4.5	36,400			41,300		
South Fork							
1.2**	19.7	89,400					
			--	--		.167	.56
Confluence 72,000***							

---

*Flow in this reach = 1380 cfs due to withdrawal of 120 cfs by HAAP. ** Flow = 840 cfs

***Calculated from N.F. Background L_o of 12,100 lbs/day and R.M. 141.2 of 84,100 lbs/day.

(1) Add HAAP Area B waste load = 48,300 lbs/day (L_o)--Gross input (includes river water content plus waste added by HAAP).

(2) Data not reliable

(3) No exercise of carbonaceous BOD in these reaches.

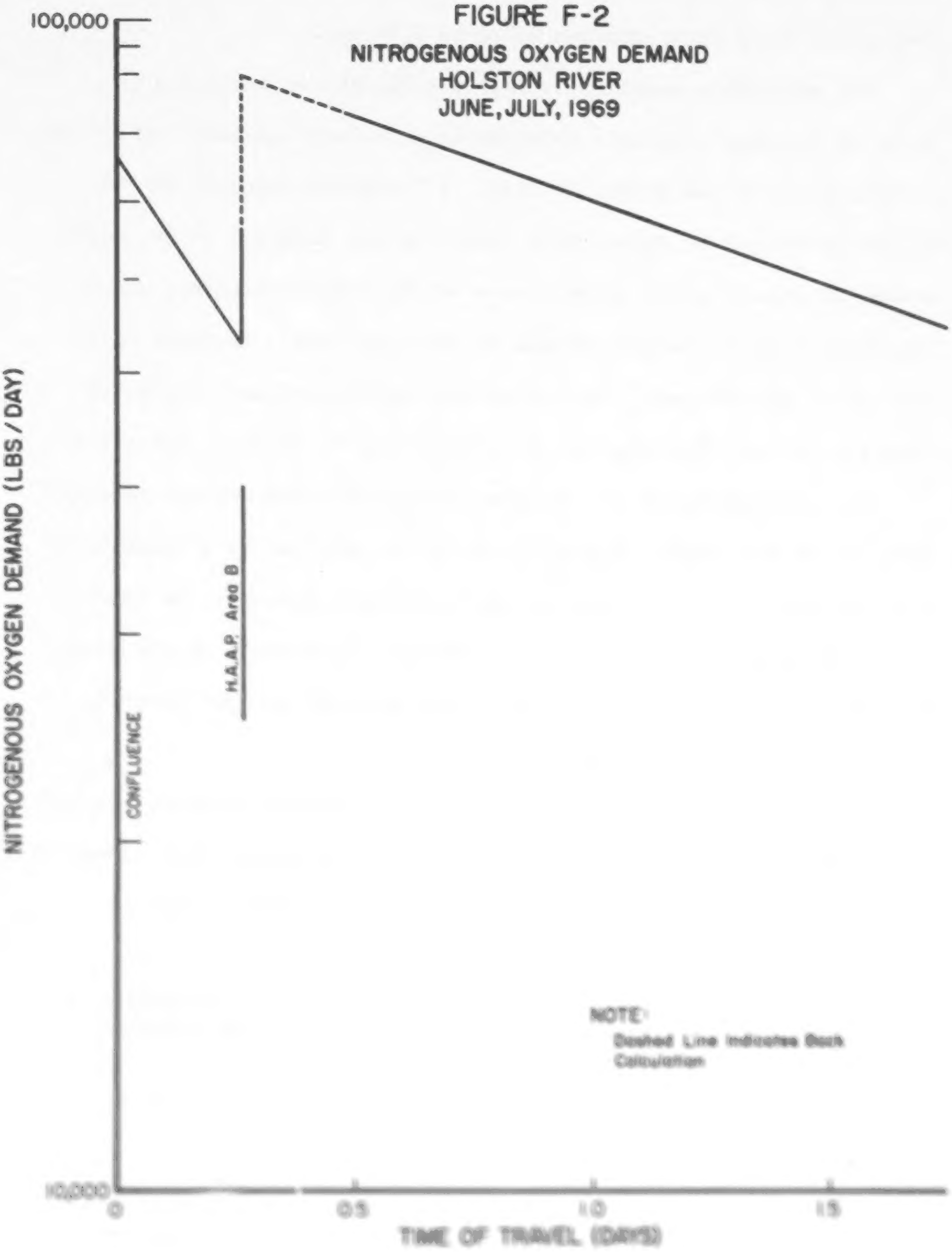


FIGURE F-2

NITROGENOUS OXYGEN DEMAND
HOLSTON RIVER
JUNE, JULY, 1969

NOTE:
Dashed Line Indicates Back Calculation

affected by the discharge but only partially mixed was 3.59 mg/l. The extrapolated calculation shows that the concentration in a completely-mixed cross section would be 2.56 mg/l.

The reaeration coefficient (k_2) was determined according to three of the many available formulae which relate hydraulic parameters, notably velocity and depth.(2)(3)(4) A "weighted average" of the K_2 values defined by these three equations was employed in the model, except in those reaches in which one of the three values was widely separated from the levels defined by the other two. In these cases this value was dropped. The reaeration coefficient was considered constant for all flow conditions. Values for K_2 shown in Table F-3.

The photosynthesis (P) and respiration (R) term was not measured directly in the field. Normally, it can be obtained as a function of the cyclical daily dissolved oxygen variation. However, the heavy pollution in the Holston River also causes fluctuations in the daily dissolved oxygen. The net P-R of oxygen produced at each sampling location is shown in Figure F-3.

As shown in this tabulation for the six reaches studied, the net effect of the extensive standing crop of aquatic weeds, when viewed on a daily basis, is to add oxygen to the flowing system. Little

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(2) Mechanism of Reaeration in Natural Streams; O'Connor, D. J. and Dobbins, W. E., Journal of the Sanitary Engineering Division, ASCE, Vol. 82, December 1956.

(3) Prediction of Stream Reaeration Rates; Churchill, M. A., Buckingham, R. A., and Elmore, H. L.; Journal of the Sanitary Engineering Divisions, ASCE, Vol. 88, July 1962.

(4) Reaeration Prediction in Natural Streams; Thackston, E. L. and Krenkel, P. A., Journal of Sanitary Engineering Division, ASCE Vol. 95, February 1969.

TABLE F-3

LOAD FACTORS AND REACTION COEFFICIENTS

HOLSTON RIVER

June - July 1969

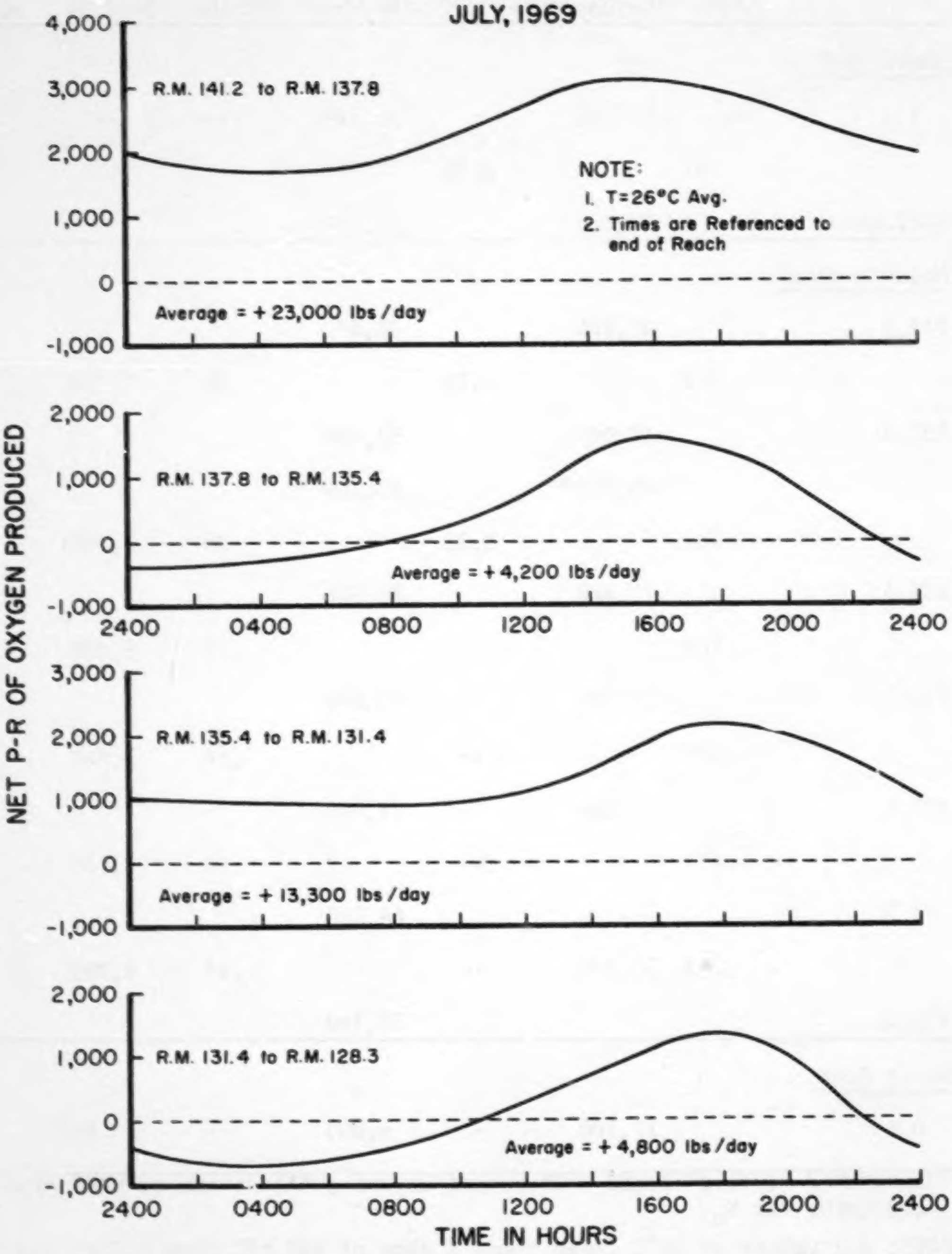
River Mile	t days	L_o lbs/day	k_r per day	N_o lbs/day	k_n per day	B lbs/day	k_2 per day
South Fork							
1.2		89,400		52,100	--	--	
	.167		0.56				.82
Confluence		72,000		70,800			
Holston River							
141.2		84,100		76,800			
	.263		0.78		.61	7,300	.41
137.9		47,000		53,000			
		45,300**		89,500**			
	.242		0.25		.14	4,920	.58
135.4		77,800		83,500			
	.167		2.10		.14	5,490	.87
131.5		29,200		77,000			
	.210		--		.14	3,860	.59
128.3		32,400		73,000			
	.032		--		.14	4,780	.45
124.3		--		64,900			
	.573	36,400	--		.14	4,900	.41
118.4				55,100			
North Fork							
0.1		12,100	-	6,000	--	85*	--

*Background benthic demand = 85 pounds/day/mi^2; **Addition of HAAP Area B (calculated for N_o)

NOTE: All values at 26°C (mean temp) & flow of 840 cfs from S.Fork and 660 cfs from N.Fork. Reaction coefficients to base 10.

FIGURE F-3

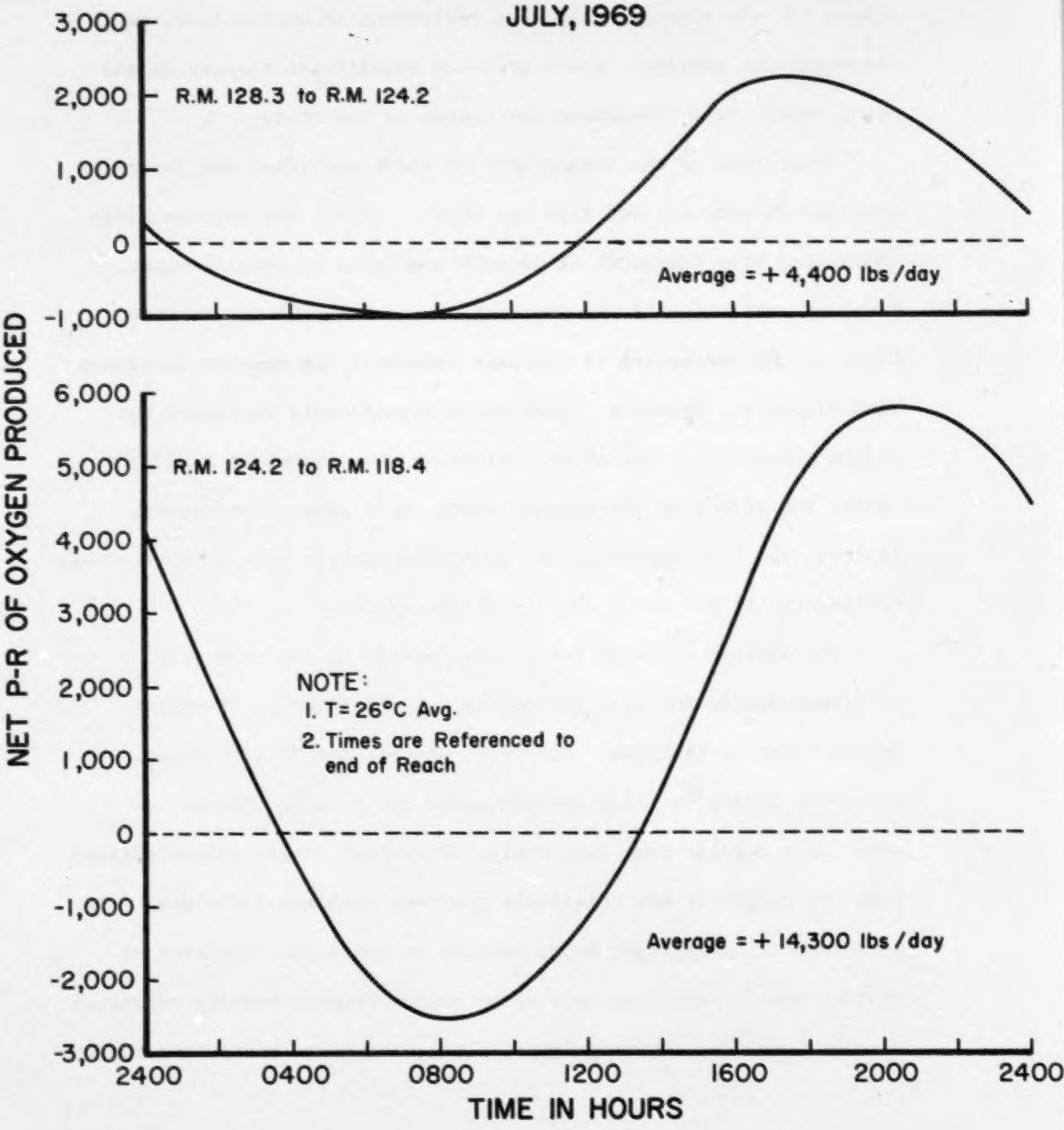
NET PHOTOSYNTHESIS LESS RESPIRATION
HOLSTON RIVER
JULY, 1969



NOTE:
1. T=26°C Avg.
2. Times are Referenced to end of Reach

FIGURE F-3 (Con't)

NET PHOTOSYNTHESIS LESS RESPIRATION
HOLSTON RIVER
JULY, 1969



NOTE:
1. T = 26°C Avg.
2. Times are Referenced to end of Reach

correlation is seen between the density of the standing crop designated for each reach, and the net production attributed to photosynthesis for the corresponding reach. Several factors may collectively have produced this condition: the difficulty in identifying precise values for the standing crop; and variations in stream flow, waste discharge and sunlight, which produced significant changes in the productivity rate throughout the course of the study.

Regardless of the sensitivity of these analysis, two important conclusions were derived from the study. First, the Holston River downstream from Kingsport is densely populated by aquatic weeds. From the confluence of the North and South Forks of the Holston River to the headwaters of Cherokee Reservoir the density increases with distance. Secondly, these weeds significanly influence the oxygen resources of the river. Although when viewed on a daily basis, the effect of the aquatic weeds would appear beneficial, in fact, the true impact of the extensive aquatic growth is extremely detrimental to the water quality of the system.

The diurnal cycle of the plants results in the production of oxygen during the daylight period, and consumption of oxygen during hours of darkness. Operation of the Fort Patrick Henry Reservoir during low flow periods calls for a "plug" release of water on a regular four hour cycle. Dissolved oxygen concentrations from the reservoir are relatively constant throughout the day. Releases during daylight hours receive an immediate injection of photosynthetic oxygen as this water passes through heavily vegetated reaches. However, water released during nighttime hours is subject only to the respiration effect of the aquatic plants and receives no benefit from photosysnthetic production. During the July 1969 study respiration of the plants in the reaches between river miles 135.4 and 118.4 ranged in the order of 0.5 mg/l reduction per hour during darkness. At some stations sampled, the variation between peak dissolved oxygen concentrations and that observed during pre-dawn hours, exceeded a difference of 6.0 mg/l.

The profusion of aquatic plants in the river results in another source of oxygen depletion. As the plants die or are torn from their roots by the turbulance of the river, they tend to be carried downstream and deposited in areas of still water. The volume of weeds transported was visually observed during the study as they accumulated on sampling gear, ropes, etc. Once deposited on the river bottom they produce beds of decaying vegetation which act as a constant oxygen sinks to waters flowing over the beds. The progressively higher rate of benthic oxygen consumption in the low less turbulant reaches of the river is thought to be a least in part, the result of this phenomenon.

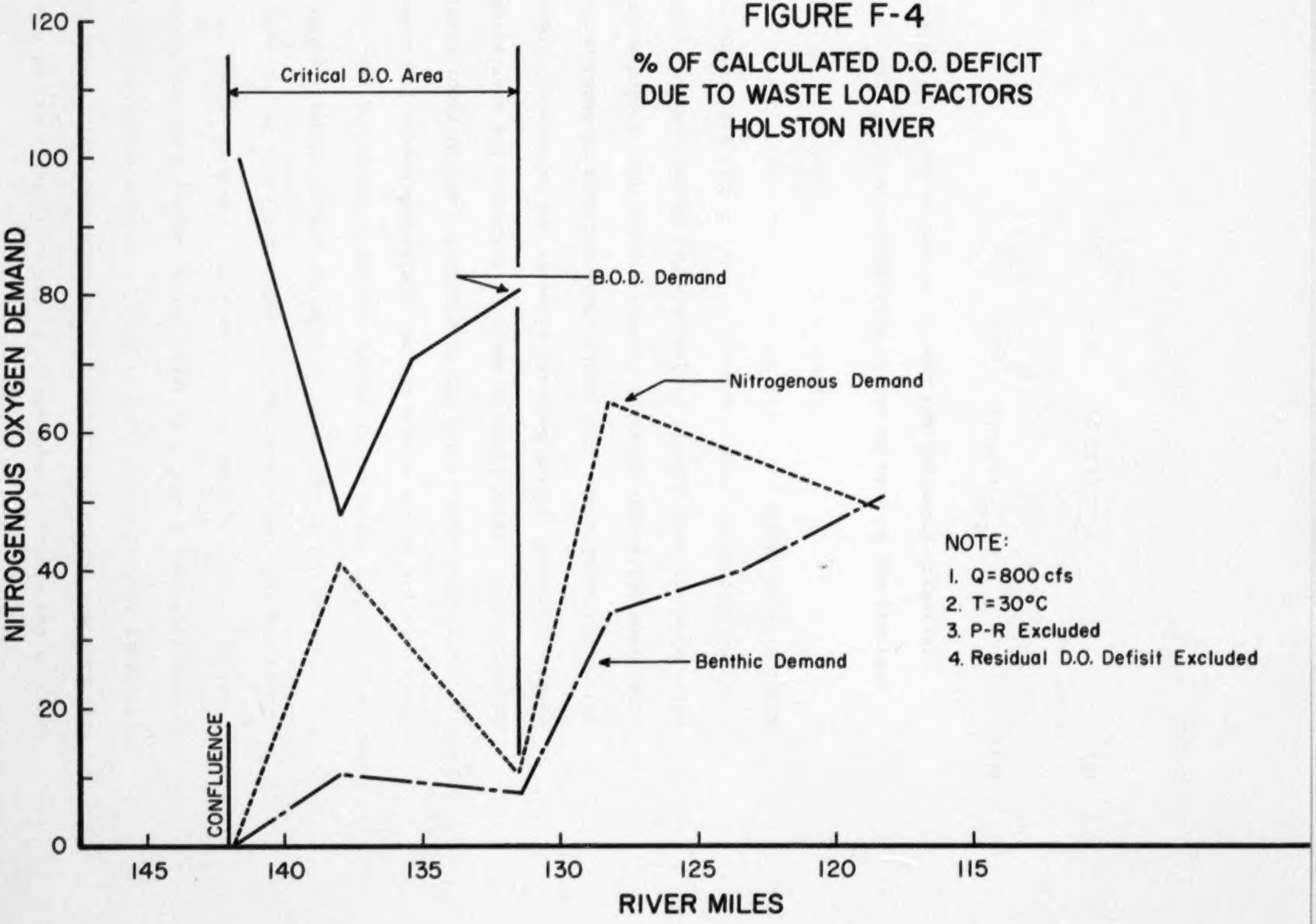
The effect of stream temperature on each of the reaction coefficients was evaluated through the following formulae:

$$k_{2_{T_2}} = k_{2_{T_1}} \quad (1.024)^{T_2-T_1} \qquad (5)$$

$$k_{r_{T_2}} = k_{r_{T_1}} \quad (1.047)^{T_2-T_1} \qquad (6)$$

FIGURE F-4

% OF CALCULATED D.O. DEFICIT
DUE TO WASTE LOAD FACTORS
HOLSTON RIVER



NOTE:
1. Q=800 cfs
2. T=30°C
3. P-R Excluded
4. Residual D.O. Defisit Excluded

$$B_{T_2} = B_{T_1} (1.065)^{T_2-T_1} \quad (7)$$

$$(P\text{-}R)_{T_2} = (P\text{-}R)_{T_1} (1.072)^{T_2-T_1 *} \quad (8)$$

B. Calculated Results

Using the factors listed in Table F-3 with appropriate temperature corrections, an extrapolation of the dissolved oxygen profile was made for critical flow and temperature conditions. (Temperature records for the Holston River indicate a maximum level of 29.5°C. The three day low flow occurring once in twenty years is 47 cfs from the North Fork and a minimum daily flow of 750 cfs from Fort Patrick Henry Dam on the South Fork.) The extrapolation was made for a flow of 800 cfs and a temperature of 30°C. To determine necessary waste reductions, the P-R term was not included. This omission has the effect of assessing what the dissolved oxygen profile would be if there were no effect from the 170 tons of bottom vegetation or if there were no vegetation present. The benthic demand was considered negligible after 30 percent BOD removal since at this level, nearly all settleable solids are removed. This assumption is verified by the background figure of 85 pounds of bottom oxygen demand per day per square mile of river.

Figure F-3 illustrates the percentage of the DO deficit due to each of the oxygen demand factors (BOD, nitrogeneous, and benthic) excluding the residual from upstream. In the critical reach, the carbonaceous oxygen demand (BOD) causes more than 50 percent of the total deficit with the nitrogenous oxygen demand (related to TKN)

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* After Welch, Limnology, pg. 167, McGraw Hill -- Second Edition 1952.

Figure F-3

Net Photosynthesis Less Respiration

Holston River

July 1967

River Reach	Net P-R of Oxygen Produced* ($\#O_2$/day)	Standing Crop (tons/mile)
RM 141.2-RM 137.8	+23,000	59.0
RM 137.8-RM 135.4	+ 4,200	52.0
RM 135.4-RM 131.4	+13,300	69.0
RM 131.4-RM 128.3	+ 4,800	102.0
RM 128.3-RM 124.2	+ 4,400	63.1
RM 124.2-RM 118.4	+14,300	78.4

*Estimates presented for temperatures = 26°C contributing as much as 40 percent. The benthic demand is fairly constant at 10 percent of the deficit in the critical reach. Downstream of Church Hill, the nitrogenous oxygen demand contributes most of the deficit. However, in this reach, dissolved oxygen would be greater than 3.0 mg/l at the critical flow and temperature, if photosynthesis and respiration were excluded. Therefore, an abatement program emphasizing carbonaceous waste reductions as a first priority will result in the most rapid improvement in stream DO concentrations. However, if present standards are to be met, removal of nitrogenous material must be considered an immediate second priority. Removal of existing benthic deposits would not significantly affect the dissolved oxygen profile.

Of the total oxygen demand throughout the study area, 55.1 percent is carbonaceous; 29.9 percent is nitrogenous and 15.0 percent results from oxidation of sludge deposits (Table F-4). Nearly 83 percent of the total oxygen demand is exerted in the area between South Fork RM 1.2 and Church Hill (RM 131.5). No additional waste discharges can be permitted in this reach if the Tennessee dissolved oxygen criterion is to be accomplished unless all parties implement even more stringent discharge requirements.

The DO profile at critical flow and temperature is also affected by the dissolved oxygen content of the water released from Fort Patrick Henry Dam. The "Recommendations" are predicated on a DO of 5.0 mg/l in the release water. If DO from the dam were only 4.0 mg/l, a removal efficiency of approximately 95 percent would be required to maintain 5.0 mg/l as a minimum at RM 131.5 (See Figure 3 in the main

TABLE F-4

DISTRIBUTION OF RIVER OXYGEN DEMAND

HOLSTON RIVER

River Mile	% of Total Demand	Distribution of Demand (% of Total)		
		Percent Carbonaceous (BOD)	Percent Nitrogenous	Percent Bottom
South Fork				
1.2				
	8.5	8.5	--	--
Confluence				
Holston River				
Confluence	34.1	16.3	14.1	3.7
137.9				
	19.8	13.9	3.8	2.1
135.4				
	20.2	16.4	2.2	1.6
131.5				
	3.8	--	2.5	1.3
128.3				
	6.0	--	3.6	2.4
124.3				
	7.6	--	3.7	3.9
118.4				
TOTAL	100.0	55.1	29.9	15.0

NOTE: T = 30°C

Q = 800 cfs

DO from Fort Patrick Henry Dam = 5 mg/l

body of this report). Changing the DO discharged from Fort Patrick Henry Dam by 1 mg/l is equivalent to approximately 3 percent waste removal or 4,320 pounds per day of carbonaceous waste and 625 pounds per day of unsatisfied nitrogenous waste. Any future expansion in the area would require a guarantee of increased DO from Fort Patrick Henry Dam and/or advanced waste treatment from both new waste dischargers and from existing users.

The rate of oxygen consumption in the river is extremely sensitive to stream temperature. Both the Tennessee Eastman Corporation and the Holston Army Ammunition Plant use large quantities of Holston River water for process cooling, collectively constituting over 70% of the entire low flow of the river system!

During the July 1969 study, the temperature of the South Fork of the Holston with a flow of 840 cfs was increased by discharges from Tennessee Eastman from a mean temperature of 15.5°C at South Fork River Mile (SFRM) 5.6, to 26.9°C at SFRM 1.2. The State of Tennessee and the Environmental Protection Agency have recently reached an agreement on temperature standards for the state's waterways which call for a maximum temperature increase of 3°C. The temperature increase of 11.4°C or 20.5°F between SFHRM 5.4 and SFHRM 1.2 resulting from discharges by the Tennessee Eastman Corporation is clearly in violation of this standard. The 1500 cfs flow of the Holston River between HRM 137.9 and HRM 135.4 increased in temperature by a total of 1.3°C or 2.34°F as measured by the Holston Army Ammunition Plant's area B discharge site. Tennessee Eastman Corporation is reportedly planning the construction of a cooling tower to reduce the overall temperature increase in the South Fork of the Holston River. However, no data are yet available relating the efficiency of this new installation to river temperature.

In addition to creating water quality conditions which are unsuitable for a healthy aquatic environment, excessive heat has also speeded up the rate at which biochemical reactions occur: a five degree centigrade temperature increase will increase the rate of carbonaceous oxygen demand by 25%; benthic oxygen demand by 37%; photosynthectic respiration by 42%; and nitrification oxygen demand by 54%. The rate of reoxygenation will, at the same time, be decreased by 13%.

A reduction of the heat discharged will reduce the rate at which oxygen is consumed and increase the rate at which it is absorbed from the atmosphere. At a treatment rate of 92% for carbonaceous and nitrogenous wastes in the study area, a five degreee centigrade decrease in water temperature will increase the dissolved oxygen concentration in the critical reach by approximately one mg/l during low flow conditions. Therefore, temperature control, particularly at the Tennessee Eastman Plant, will have a dual benefit of assisting in the maintenance of both temperature and dissolved oxygen standards in the river system.

The effect of photosynthesis and respiration was evalutated before and after the calculated waste removals. The assumption was made that P-R values observed during the field operations would remain constant except for variations due to temperature changes as predicted by equation 8. A net total of 60,000 pounds per day of dissolved oxygen is added to the study area as a result of photosynthesis at a temperature averaging 26°C. This total is increased by 32 percent for the critical temperature of 30°C. Therefore, the net benefit from photosynthesis and respiration on the oxygen balance is nearly equivalent to reaeration. However, cyclical daily variation would cause the dissolved oxygen to be completely depleted during the night in the entire study area downstream of RM 141.2 with no reduction in wastes from present levels, given critical flow and temperature.

Even at the levels of treatment recommended (92% reduction carbonaceous and nitrogenous wastes) the 3.0 mg/l dissolved oxygen water quality standard will be violated at critical flow conditions if the effect of the aquatic weeds is considered. A variety of water quality management techniques have been proposed to mitigate the effects of the plants including harvesting and nutrient control. Of these the approach of reducing nutrients in the Holston Basin appears to be the most effective means of control. The reduction of 92% nitrogen derived from the mathematical model is based upon total Kjeldahl Nitorgen removal. However, oxidation of TKN to the nitrate form (NO_3-) will simply place this nutrient in its most easily assimilable form for utilization by aquatic weeds in the river. Should this approach be followed, the net result would likely be an increase, rather than a decrease, in the rate of oxygen consumption in the river. For this reason it is imperative that all forms of nitrogen be removed to a minimum level of 92% of the 1969 rate.

Studies have shown that nutrients contained in the sediments of the river bottom and in the existing standing crop of weeds may be adequate to supply nutrient needs for possibly years into the future. Although nutrient control will ultimately reduce the undesirable effects of the weeds, additional short term water quality management techniques may be required to insure maintenance of acceptable dissolved oxygen levels. These techniques might include low flow augmentation from the Fort Patrick Henry Reservoir; improvement in D.O. levels from the reservoir; in-stream reaeration; temperature control; or a combination of these. Additional study should be directed at finding both short and long term solutions to the aquatic weed problem.

Appendix G

SAMPLING PROCEDURE

The Holston River study was conducted June 14-18, 1969, and July 25-29, 1969. Most stream and effluent data were collected in July.

Five major waste sources were sampled during July: Tennessee Eastman Company, Holston Army Ammunition Plant (HAAP), Mead Paper Company, the Kingsport sewage treatment plant, and Holliston Mills. With the exception of the HAAP, samples were collected by plant personnel and delivered to a representative of Tennessee Division of Stream Pollution Control, who, in turn, delivered it to the FWQA mobile laboratory for analysis. All anlytical methods were peformed in accordance with Standard Methods for the Analysis of Water and Wastewater, 12th Edition, except for nitrogen and phosphorus determinations which were performed on a Technicon Auto-analyzer.* Total organic carbon determinations were made on a Beckman Model 915 total carbon analyzer.

Discharge rates for these sources were obtained by State personnel from the industries. Samples were collected initially at each discharge point during the river study at times coinciding with the passage of the "dye slug" past the respective outfalls and composited for a period of 24 hours thereafter.

The HAAP was sampled by FWQA personnel. Area A of the plant, located on the South Fork of the Holston River, was sampled June 16 and 17, 1969. The main outfall was sampled by use of an automatic sampler which collected one sample each hour. This outfall was gauged using a flow meter to determine discharge value. Two small sewers were also sampled during this period. Discrete hourly samples were collected from both outfalls, and the samples from the two were composited each hour. Discharge from each line was determined by timing the passage of a dye tracer and measuring the area of the flowing cross section.

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* Mention of trade names or commercial products does not constitute endorsement by the Environmental Protection Agency.

Area B of the HAAP was sampled during both portions of the study. Samples were collected at the water intake houses on approximately two-hour intervals during both studies to be utilized as background values. All three cooling water discharges were sampled during the June study, which included bi-hourly samples over a 16-hour period. The four outfalls carrying process waste were sampled during both portions of the study. Fourteen hours of sampling were completed during the June study, when sampling was terminated due to rainfall. Sampling was resumed at the same hour that it had been discontinued during the July study and continued on a twice per hour basis for 24 hours at each of the four outfalls. Sampling at process lines 3a, 3b, and 3c, as well as the main outfall ditch, (during the June study) was by grab sample on a twice per hours basis. Sampling from the main outfall ditch during the July study was performed with the automatic sampling device and samples were composited at four-hour intervals. Discharge measurements were made on each process line outfall using the dye technique previously noted and on main outfall using a flow meter.

Preliminary work performed on the Holston River during the June 14-18 study consisted of releasing dye to evaluate mixing parameters and time of travel during reduced weekend flows from Fort Patrick Henry dam. Rhodamine WT dye was released into Tennessee Eastman's Hale's Branch outfall and sampled at cross sections in the river at several locations below this point. Uniform concentrations of the dye in the cross-section was considered to be representative of uniform mixing of the waste into the river. The first dye release took place as the low flow in the peaking power cycle passed the Tennessee Eastman Plant, while the second release took place during the passage of a peak. Fluorometers were used at downstream locations to determine dye concentration, and arrival time was computed based upon the maximum dye concentration at each downstream point.

The main river study took place during the period from midnight, July 25, to 1:15 p.m., July 29, 1969, over the portion of the river between the Fort Patrick Henry Dam to the headwaters of the Cherokee Reservoir at RM 115.9. The study commenced with a dye release at 2:00 a.m. at South Fork Holston River Mile 1.2 (Richfield Bridge). Samples were collected for BOD, nitrogen, and phosphorus series, organic carbon, solids, pH, and alkalinity at this location at approximately 1.5, 3, 6, 12, 18, and 24 hours after the dye release. Dissolved oxygen and temperature evaluations were performed a minimum of once every two hours at third points along the lateral cross section at each location for a total of 26 hours after sampling was initiated.

Teams located downstream of the initial point, and equipped with fluorometers, analyzed dye concentration in the river. As soon as the dye concentration peaked at the sampling station, samples were collected at that location as previously discussed, and the fluorometer team moved to a station farther downstream. In this way, a full set of analyses was available for a discrete mass of water as it passed downstream, as well as six trailing masses of water between 1.5 and 24 hours later. At each station, a complete diurnal dissolved oxygen profile was also performed to provide an estimate of the productivity rate. Sample sets were also collected from the North Fork and at a control station in the South Fork of the Holston River to serve as background data.

A team from FWQA and one from TVA, working independently measured the benthic oxygen demand, utilizing benthic respirometers. Both teams performed studies during the June survey and the TVA team followed up this work with a second study during the July portion of the survey. Each team used respirometers to evaluate oxygen uptake from benthic deposits on randomly selected transects within the study area.

FWQA biologists from the Southeast Water Laboratory performed extensive biological studies during both the June and July portions of the survey. Their effort was directed primarily at quantifying the extensive mass of attached aquatic weeds as to species, volume, and distribution in the river. In conjunction with ground evaluations, an aerial survey was performed with motion picture film to evaluate the extent of the standing crop. Sampling locations are listed in Table G-1.

Table G-1

SAMPLING STATIONS

River Study

NFHRM 0.1 -- North Fork Holston at RM 0.1 (Rotherwood Bridge)

SFHRM 5.6 -- South Fork Holston at RM 5.6

SRHRM 1.2 -- South Fork Holston at RM 1.2 (Richfields Bridge)

HRM 141.2 -- Holston River at RM 141.2 (confluence of North and South Forks at the HAAP railroad bridge)

HRM 137.9 -- Holston River at RM 137.9 (HAAP's Igloo Bridge)

HRM 135.4 -- Holston River at RM 135.4 (Smith Bend)

HRM 131.5 -- Holston River at RM 131.5 (Church Hill Bridge)

HRM 128.3 -- Holston River at RM 128.3 (St. Gobain Company pipeline)

HRM 124.3 -- Holston River at RM 124.3 (Christian Bend)

HRM 118.4 -- Holston River at RM 118.4 (Surgoinsville Bridge)

HRM 115.9 -- Holston River at RM 115.9 (Miller Flats)

Holston Army Ammunition Plant

AME -- Area A, main effluent ditch

ATB -- Area A, top and bottom sewer outfall composite upstream of AME

B209 -- Area B, water intake, pump station, building 209

B201 -- Area B, water intake, pump station, building 201

BC1 -- Area B, cooling water effluent stream #1

BC3a -- Area B, cooling water effluent stream #3a

BC3b -- Area B, cooling water effluent stream #3b

BP3a -- Area B, process waste effluent stream from line 3a

BP3b -- Area B, process waste effluent stream from line 3b

BP3c -- Area B, process waste effluent stream from line 3c

B4b -- Area B, process waste ditch from ammonia area

BME -- Area B, main effluent, process anc cooling water combined dishcarge at the plant's monitor

Tennessee Eastman

TEHB -- Hale's Branch process anc cooling water discharge

TEL1 -- Long Island outfall effluent

TESP -- South Plant effluent (lagoon discharge)

APPENDIX H

SUMMARY OF OBSERVED DATA

Table H-1 - Water Quality Survey Data

Table H-2 - Industrial Effluent Data

Table H-3 - Around-the-Clock Dissolved Oxygen Survey

TABLE H-1

WATER QUALITY SURVEY DATA
HOLSTON RIVER

Station	Collected Date (1967)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
S. Fork Mi. 5.6	7/26	0001	15.2	1.6	3.0	3	5	0	0.52	0.16	1.175	.006	.021	7.0	58	1	5
Mi. 5.6	7/26	0030	--	--	--	--	--	--	0.26	0.02	1.435	.006	.012	--	--	--	--
Mi. 5.6	7/26	1020	15.8	--	7.8	3	25	22	0.45	0.15	1.260	.050	.061	7.5	60	2	8
Mi. 5.6	7/26	2237	15.0	1.2	1.8	1	11	3	0.34	0.05	1.130	.021	.030	7.3	62	2	7
Sluice Mi. 1.0	7/26	0106	16.0	4.6	5.4	3	3	0	0.40	0.19	1.050	.007	.034	7.3	77	4	6
Mi. 1.0	7/26	1215	22.0	5.8	7.8	4	16	4	0.50	0.31	0.770	.012	.067	7.6	120	8	8
Mi. 1.0	7/27	0025	25.0	29	41	13	10	3	0.46	0.28	0.265	.008	.036	7.3	120	10	7
N. Fork Mi. 0.1	7/26	0400	25.0	1.2	2.8	1	9	1	0.49	--	1.340	.005	.017	7.9	74	1100	10
Mi. 0.1	7/26	1600	28.0	2.6	4.2	4	6	3	0.35	0.11	0.825	.022	.043	8.4	71	360	4
Mi. 0.1	7/27	0400	26.0	1.1	3.1	4	11	5	0.33	0.05	0.868	.009	.030	7.9	79	320	4
R. Chan. Mi. 1.2	7/26	0200	20.8	7.4	12	3	10	0	1.67	1.20	1.140	.088	.172	7.4	558	11	10
Mi. 1.2	7/26	0330	24.6	15	24	6	14	2	3.34	2.65	0.935	.123	.250	7.2	36	15	17
Mi. 1.2	7/26	0500	24.2	11	20	5	16	4	1.55	0.99	0.935	.086	.158	7.4	68	15	17
Mi. 1.2	7/26	0800	26.1	15	21	5	5	0	3.02	2.25	0.800	.110	.242	7.3	72	16	11
Mi. 1.2	7/26	1400	27.5	16	24	5	24	4	1.49	0.78	0.972	.137	.258	7.4	77	17	36
Mi. 1.2	7/26	2010	30.0	14	19	5	12	2	1.79	1.09	0.792	.125	.229	7.4	79	20	17
Mi. 1.2	7/27	0208	26.0	11	16	5	22	7	2.12	1.56	0.782	.150	.259	7.5	62	20	14
L. Chan Mi. 1.2	7/26	1400	26.8	7.2	12.5	5	13	3	3.25	2.53	0.968	.131	.285	7.3	69	14	17
Mi. 1.2	7/26	2015	29.0	8.4	13	5	9	3	4.62	3.66	0.780	.138	.353	7.3	66	14	11
Mi. 1.2	7/27	0208	26.0	7.6	13	4	14	5	3.86	3.43	0.730	.143	.299	7.5	67	14	8
L. Chan Mi.141.2	7/26	0615	20.2	--	--	5	5	0	1.44	1.06	0.945	.044	.094	7.4	60	330	7
Mi.141.2	7/26	0710	22	9.2	12	5	12	3	2.06	1.49	0.810	.053	.110	7.3	54	340	12
Mi.141.2	7/26	0840	23.1	9.4	15	5	9	1	3.02	1.90	0.610	.962	.182	7.2	42	50	11
Mi.141.2	7/26	1207	26	7.6	12	6	15	9	2.54	1.97	0.595	.074	.200	7.2	71	22	9
Mi.141.2	7/26	1830	29.0	4.2	8.0	5	8	1	2.55	1.98	0.725	.082	.229	7.2	72	18	13
Mi.141.2	7/26	2400	28	6.2	9.6	5	10	4	2.94	2.08	0.438	.054	.266	7.2	55	18	10
Mi.141.2	7/27	0600	26.0	4.6	8.8	4	13	7	2.68	2.25	0.385	.125	.274	7.4	73	16	8
R. Chan. Mi.141.2	7/26	1207	26	6.8	11	5	10	3	1.87	1.34	0.665	.064	.164	7.2	56	145	8
Mi.141.2	7/26	1830	28.1	5.4	9.4	5	11	1	1.67	1.13	0.745	.042	.219	7.3	64	88	13
Mi.141.2	7/26	2400	27.7	5.0	7.2	5	9	4	2.11	1.52	0.500	.075	.220	7.3	61	73	13
Mi.141.2	7/27	0600	26.2	4.4	5.8	4	11	6	2.24	1.80	0.499	.093	.204	7.4	72	83	8

Table H-1

Water Quality Survey Data
Holston River

Station	Collected Date (1969)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. as P ppm P	pH	Ak. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
L.Chan. Mi.137.9	7/26	1155	24	1.8	2.9	4	9	5	1.49	1.09	0.880	.064	.106	7.3	57	380	7
Mi.137.9	7/26	1325	26	3.8	6.4	4	6	3	1.67	1.15	0.685	.024	.063	7.2	58	430	5
Mi.137.9	7/26	1500	26.5	4.0	6.2	5	9	5	1.47	1.00	0.685	.036	.095	7.2	56	370	4
Mi.137.9	7/26	1800	28	2.4	4.0	3	10	5	1.52	1.13	0.617	.053	.133	7.3	72	240	7
Mi.137.9	7/26	2400	27.5	5.8	8.2	5	2	1	1.71	1.31	0.580	.084	.186	7.4	64	150	7
Mi.137.9	7/27	0530	26.8	2.8	4.6	4	8	8	1.70	1.34	0.387	.072	.140	7.5	77	132	7
Mi.137.9	7/27	1130	27.0	3.8	6.0	4	13	3	2.01	1.66	0.335	.089	.173	7.2	65	100	4
R.Chan. Mi.137.9	7/26	1230	25	5.3	7.9	5	12	6	3.52	2.76	1.990	.034	.080	7.7	45	550	7
Mi.137.9	7/26	1800	28	8.8	12	4	13	7	1.54	1.00	0.825	.022	.085	7.4	65	300	7
Mi.137.9	7/26	2400	27.1	9.6	13	6	11	7	3.98	2.75	3.300	.038	.110	7.8	46	95	8
Mi.137.9	7/27	0530	27.0	12	15	4	8	6	4.34	3.45	1.822	.042	.102	7.4	52	147	8
Mi.137.9	7/27	1145	26.9	13	16	5	19	7	4.58	3.85	1.955	.040	.108	8.7	52	146	7
RM135.4	7/26	1730	27	2.1	3.5	4	6	3	2.04	1.62	1.190	.022	.057	7.6	60	480	4
RM 135.4	7/26	1840	27	1.8	3.6	4	8	3	2.18	1.71	1.065	.033	.064	7.3	55	420	4
RM 135.4	7/26	2000	27	2.2	5.6	4	1	0	2.18	1.73	0.968	.028	.058	7.3	57	380	4
RM 135.4	7/26	2300	27.9	1.4	3.2	3	2	2	2.04	1.62	0.805	.013	.050	7.4	60	290	13
RM 135.4	7/27	0500	28.3	2.2	3.8	3	9	7	2.45	1.95	1.320	.056	.018	7.4	58	160	4
RM 135.4	7/27	1100	27.8	2.0	4.6	3	12	10	2.42	2.03	0.670	.044	.100	7.5	66	146	6
RM 135.4	7/27	1705	30	2.0	6.0	4	9	7	2.68	2.27	0.675	.086	.146	7.7	62	124	3
RM 131.5	7/26	2115	26	1.0	1.9	3	2	0	1.77	1.45	1.260	.030	.050	7.3	60	430	3
RM 131.5	7/26	2215	26	1.4	2.4	3	4	0	2.21	1.71	1.130	.031	.063	7.5	50	460	6
RM 131.5	7/26	2345	26	1.0	1.8	3	2	2	2.13	1.72	0.970	.012	.042	7.4	58	370	4
RM 131.5	7/27	0255	26	<0.2	1.9	3	2	1	2.04	1.69	0.823	.033	.062	7.4	59	280	3
RM 131.5	7/27	0845	26	1.1	20	3	7	0	2.28	1.89	0.779	.058	.085	7.4	62	190	5
RM 131.5	7/27	1505	29	1.1	2.7	4	14	7	2.43	1.94	0.654	.044	.092	8.2	65	150	3
RM 131.5	7/27	2045	29	1.4	3.0	4	7	3	2.54	2.14	0.610	.056	.112	7.7	64	134	3
RM 128.3	7/27	0235	23	1.7	2.5	3	3	0	1.80	1.40	1.254	.031	.062	7.5	62	310	4
RM 128.3	7/27	0310	24	1.7	1.7	3	5	4	1.91	1.49	1.210	.035	.052	7.5	62	440	3
RM 128.3	7/27	0435	24	2.6	4.4	3	7	1	2.15	1.57	1.208	.046	.070	7.4	63	410	7
RM 128.3	7/27	0730	25	0.5	2.0	3	3	0	2.09	1.75	0.918	.021	.046	7.4	62	360	3
RM 128.3	7/27	1330	26.7	0.8	2.7	4	17	5	2.20	1.79	0.735	.035	.062	7.6	63	230	6
RM 128.3	7/27	1930	29.0	2.0	4.3	4	7	1	2.29	1.88	0.790	.038	.094	8.0	68	162	4

Table H-1

Water Quality Survey Data

Holston River

Station	Collected Date (1969)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as P	O-PO_4 ppm P	Tot. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
RM 124.2	7/27	0815	24	1.2	1.7	3	2	0	1.86	1.51	1.327	.036	.069	7.3	63	380	5
RM 124.2	7/27	0945	24.5	0.7	1.8	3	1	0	1.78	1.47	1.260	.032	.060	7.3	64	380	4
RM 124.2	7/27	1115	25.0	0.6	2.3	3	40	34	0.93	0.54	1.940	.017	.053	7.3	--	166	70
RM 124.2	7/27	1440	26.7	0.8	2.2	3	18	7	1.98	1.57	1.070	.019	.044	7.9	61	380	5
RM 124.2	7/27	2015	28.2	1.3	2.7	3	6	2	1.94	1.57	0.804	.024	.058	7.9	63	280	6
RM 124.2	7/28	0255	28.0	1.6	3.6	3	7	5	2.11	1.75	0.785	.125	.162	7.3	66	172	4
RM 124.2	7/28	0830	28	1.8	3.6	4	3	0	2.30	1.95	0.690	.039	.076	7.4	67	144	4
RM 118.4	7/27	2230	26	1.0	1.9	3	1	1	1.40	0.93	1.510	.019	.038	7.8	62	360	2
RM 118.4	7/27	2330	26	3.2	4.7	4	5	2	1.54	0.99	1.530	.040	.061	7.5	56	410	4
RM 118.4	7/28	0100	25.5	1.9	3.3	4	6	2	1.61	1.03	1.385	.023	.037	7.4	58	370	3
RM 118.4	7/28	0400	25.0	2.2	3.5	4	9	6	1.58	1.22	1.320	.045	.055	7.4	66	340	5
RM 118.4	7/28	1000	27.0	1.1	3.3	3	1	0	1.58	1.22	1.180	.014	.040	7.4	68	170	3
RM 118.4	7/28	1600	30	1.5	3.2	4	3	0	1.57	1.11	1.135	.030	.067	8.5	67	180	4
RM 118.4	7/28	2200	29.0	1.0	2.2	4	8	3	1.80	1.32	1.085	.053	.098	7.8	70	145	4
RM 115.3	7/28	0615	25.0	0.2	0.4	3	4	2	1.25	0.86	1.615	.078	.089	7.3	64	360	3
RM 115.3	7/28	0645	25.0	0.8	1.7	3	1	0	1.32	0.88	1.590	.030	.040	7.3	64	350	3
RM 115.3	7/28	0815	25.0	0.9	1.5	3	1	0	1.40	0.95	1.520	.030	.037	7.4	65	350	3
RM 115.3	7/28	1115	27.0	0.7	2.2	3	2	0	1.40	1.01	1.418	.022	.040	7.4	64	220	3
RM 115.3	7/28	1715	29.0	1.1	1.8	4	3	0	1.32	0.86	1.420	.018	.050	8.2	68	170	4
RM 115.3	7/28	2315	30.0	0.7	1.7	4	4	0	1.50	0.89	1.360	.084	.118	8.1	67	170	4

Table H-2

INDUSTRIAL EFFLUENT DATA

Holston River

Station	Collected Date (1969)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
TEC S.Plant	July 25-26	2000-0800	--	165	320	63	60	10	0.42	.02	1.000	.008	.036	7.3	62	2	23
LongIs.	25-26	2000-0800	--	86	204	74	86	70	165	140	.560	4.2	7.04	6.5	113	124	23
Hale Br.	25-26	2000-0800	--	13.2	19.8	3	8	0	2.37	.40	.426	.018	0.63	7.4	63	6	12
Mead Pa.	25-26	2000-0800	--	116	168	40	160	42	2.86	0.01	.010	.162	.284	7.3	76	200	150
Kingsport STP	25-26	2000-0800	--	11	25	20	12	12	8.10	5.60	1.180	5.5	7.60	7.4	112	44	7
Holliston Mills	26-27	2000-0800	--	545	1005	66	28	15	10.1	0.19	0.155	5.0	6.70	7.3	60	380	8

HOLSTON ARMY AMMUNITION PLANT, AREA "A", KINGSPORT, TENNESSEE

Holston River

Station	Collected Date (1969)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
	June																
Main Ef.	17	0815	33	29	51	8	31	7	0.60	0.10	1.14	<.005	0.066	6.7	64	--	--
Main Ef.	17	1000	30	--	--	--	--	--	1.65	0.41	1.15	<.005	.136	6.9	68	--	--
Main Ef.	17	1200	26	18	44	9	10	5	.23	<.05	1.17	<.005	.239	6.9	68	--	--
Main Ef.	17	1400	25	--	--	--	--	--	.19	<.05	1.17	<.005	.283	7.2	69	--	--
Main Ef.	17	1620	27	20	49	8	1	0	.28	<.05	1.31	<.005	.036	7.3	67	--	--
Main Ef.	17	1810	27	--	--	--	--	--	.37	<.05	1.29	<.005	.030	7.4	69	--	--
Main Ef.	17	2012	27	22	59	9	0	0	.23	<.05	1.24	<.005	.030	7.4	65	--	--
Main Ef.	17	2210	27	--	--	--	--	--	.25	<.05	1.29	<.005	.016	7.6	69	--	--
Main Ef.	17	2400	27	14	53	10	39	7	.19	<.05	1.14	<.005	.160	7.6	65	--	--
Main Ef.	18	0200	28	--	--	--	--	--	.23	<.05	1.25	<.005	.028	7.4	75	--	--
Main Ef.	18	0400	27	31	60	16	19	14	.26	<.05	1.22	<.005	.006	7.5	76	--	--
Main Ef.	18	0600	27	--	--	--	--	--	.24	<.05	1.11	.072	.122	7.4	68	--	--
Main Ef.	18	0820	26	18	49	11	58	2	.22	<.05	1.28	<.005	.011	7.3	62	--	--
Top Bottom Composite	17	1010	25-27	31	40	3	11	0	1.38	0.68	1.24	<.005	0.062	6.8	69	--	--
"	17	1200	24-26	15	18	2	19	10	.32	.13	1.24	<.005	.026	7.2	64	--	--
"	17	1400	24-27	--	--	--	--	--	.34	.18	1.21	<.005	.120	7.4	64	--	--
"	17	1620	26-25	8	10	2	8	4	.48	.28	1.27	<.005	.127	7.3	61	--	--
"	17	1805	26	--	--	--	--	--	.51	.23	1.24	<.005	.136	7.6	62	--	--
"	17	2005	25-26	8	12	2	0	0	.38	.22	1.26	<.005	.040	7.2	61	--	--
"	17	2206	24-26	--	--	--	--	--	.42	.22	1.25	<.005	.016	7.7	65	--	--
"	17	2400	23-25	11	16	4	0	0	.71	.48	1.23	<.005	.008	7.6	62	--	--
"	18	0200	23-27	--	--	--	--	--	.69	.42	1.24	<.005	.165	7.4	66	--	--
"	18	0400	23-25	11	16	3	0	0	.33	.20	1.26	<.005	.010	7.3	65	--	--
"	18	0600	23-25	--	--	--	--	--	.58	.28	1.19	.099	.134	7.1	63	--	--
"	18	0826	21-24	12	16	3	0	0	2.24	1.81	1.24	.005	.030	7.3	63	--	--

HOLSTON ARMY AMMUNITION PLANT, AREA "B", KINGSPORT, TENNESSEE

Holston River

Station	Collected Date (1969)	Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
Water Intake																	
Bldg.209	6/18	0902	24.2	--	--	7	22	6	2.30	2.09	0.72	.044	.121	7.5	59	--	--
Bldg.209	6/18	1045	24.8	--	--	--	--	--	2.30	1.80	0.83	.128	.242	7.6	51	--	--
Bldg.209	6/18	1215	25.5	--	--	6	20	8	2.57	1.90	0.68	.042	.144	8.1	56	--	--
Bldg.209	6/18	1315	25.5	--	--	--	--	--	2.36	1.80	0.84	.055	.152	8.1	68	--	--
Bldg.209	6/18	1600	24.5	--	--	7	29	15	2.35	2.09	0.96	.090	.200	8.0	77	--	--
Bldg.209	6/18	1755	21.9	--	--	--	--	--	3.06	2.82	1.19	.278	.615	8.0	133	--	--
Bldg.209	6/18	2020	20.3	--	--	5	--	--	1.47	1.29	1.28	.082	.262	8.2	130	--	--
Bldg.209	6/18	2210	19.5	--	--	--	--	--	1.32	1.04	1.23	.054	.198	8.3	126	--	--
Cooling																	
Water#1	6/18	0821	29.5	--	--	7	6	0	3.25	2.69	0.26	.078	.226	7.4	51	--	--
"	6/18	1020	31.0	--	--	--	--	--	3.22	2.47	0.41	.184	.320	7.4	58	--	--
"	6/18	1225	30.0	--	--	6	22	6	3.52	2.73	0.38	.084	.260	7.5	57	--	--
"	6/18	1415	27.5	--	--	--	--	--	3.10	2.34	0.62	.121	.258	7.6	64	--	--
"	6/18	1605	28.5	--	--	8	34	6	2.92	2.21	0.85	.190	.326	7.6	65	--	--
"	6/18	1756	22.0	--	--	--	--	--	1.44	1.03	0.94	.202	.385	7.9	73	--	--
"	6/18	2024	20.2	--	--	2	86	15	1.31	0.93	1.04	.096	.182	7.9	62	--	--
"	6/18	2202	20.0	--	--	--	--	--	1.00	0.90	1.02	.055	.120	7.6	66	--	--
4-b																	
Ammonia	6/18	0908	27.6	--	--	357	72	4	490	410	12.2	.010	.010	10.8	2200	--	--
"	6/18	1155	28.0	--	--	--	--	--	461	388	10.3	.100	.168	10.8	1900	--	--
"	6/18	1158	28.0	--	--	289	168	62	393	324	8.65	.023	.072	8.8	1750	--	--
"	6/18	1400	2.75	--	--	--	--	--	422	352	9.70	.028	.096	10.9	1900	--	--
"	6/18	1555	28.3	--	--	438	278	92	1152	460	12.7	.076	.160	10.9	2550	--	--
"	6/18	1810	26.0	--	--	--	--	--	650	548	15.4	.094	.232	18.8	2950	--	--
"	6/18	1955	28.3	--	--	1114	315	42	915	880	20.0	.015	.106	11.1	3950	--	--
"	6/18	2200	28.0	--	--	--	--	--	1000	955	19.3	<.005	.088	11.3	4100	--	--
4-a																	
Monitor	6/18	0917	30.2	--	--	10	12	5	13.1	12.6	3.13	.065	.126	8.6	117	--	--
"	6/18	1103	30.7	--	--	--	--	--	7.72	6.50	4.08	.140	.210	8.6	33	--	--
"	6/18	1155	30.6	--	--	9	19	12	8.22	7.26	3.00	.042	.156	8.7	27	--	--
"	6/18	1355	31.0	--	--	--	--	--	8.17	6.80	3.03	.071	.160	8.7	92	--	--
"	6/18	1550	28.6	--	--	9	25	8	8.32	7.25	5.55	.063	.140	8.7	117	--	--
"	6/18	1810	30.0	--	--	--	--	--	6.00	4.92	6.50	.104	.182	8.2	120	--	--
"	6/18	1915	28.0	--	--	9	93	18	9.90	9.28	6.85	.034	.164	6.1	112	--	--
"	6/18	2145	27.0	--	--	--	--	--	6.30	5.40	5.25	.049	.111	8.6	100	--	--

HOLSTON ARMY AMMUNITION PLANT, AREA "B", KINGSPORT, TENNESSEE

Holston River

Station	Collected Date (1969)	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Totl. as P ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
Monitor Ditch	7/29	1900-2400	—	24	32	6	23	2	5.74	4.22	3.30	.092	.350	8.2	38	70	15
"	7/29	0100-0600	--	30	42	7	16	6	5.84	4.58	4.00	.044	.152	8.6	37	53	8
"	7/29	0700-1200	—	32	40	6	21	8	9.20	8.55	3.72	.062	.225	8.7	34	68	13
	" 7/29	1300-1800	—	36	56	8	22	7	8.35	7.21	4.97	.060	.215	8.4	30	76	7
3-h Process	6/18	0832	30.5	42	98	28	19	13	2.99	1.90	.92	.013	.086	7.4	70	--	--
"	6/18	1030	31.4	--	--	--	--	--	5.85	2.08	3.00	.042	.140	6.9	68	—	—
"	6/18	1230	30.0	60	86	47	38	20	5.17	2.56	3.77	.007	.110	6.7	59	—	—
"	6/18	1420	29.5	--	—	--	--	--	4.37	2.07	2.00	.005	.064	7.0	65	—	—
"	6/18	1610	29.5	66	142	39	50	32	3.80	1.81	2.92	.005	.090	6.7	61	--	--
"	6/18	1805	28.5	--	—	—	—	—	6.70	2.14	5.10	.115	.208	6.1	70	—	--
"	6/18	2034	26.5	55	155	67	64	32	3.95	1.57	2.72	.011	.048	7.9	65	--	--
"	6/18	2211	25.5	--	--	--	--	--	3.90	1.43	3.14	.007	.071	6.7	73	--	—
"	7/29	0200	--	62	90	7	4	0	5.00	0.49	1.16	.032	.113	7.4	72	9	10
"	7/29	0800	--	114	158	28	27	22	5.08	1.44	2.55	.055	.125	6.3	72	13	20
"	7/29	1400	—	54	86	16	22	18	4.16	2.17	1.46	.044	.153	7.2	58	15	17
"	7/29	2000	—	80	112	11	13	6	2.96	0.95	1.82	.042	.081	7.1	75	10	12
3-c Process	6/18	0827	31.9	54	93	18	15	11	3.00	2.02	1.00	.015	.292	7.3	78	--	--
"	6/18	1025	31.7	--	--	--	--	--	2.30	1.55	1.11	.012	.178	6.3	79	--	--
"	6/18	1235	30.0	55	80	11	20	11	4.07	2.30	1.11	.007	.278	6.5	72	—	—
"	6/18	1416	31.0	--	—	—	--	—	5.45	2.88	2.92	.012	.310	5.7	66	--	--
"	6/18	1607	31.5	62	118	22	24	12	3.35	2.09	1.84	.018	.148	6.0	74	—	--
"	6/18	1800	28.5	--	--	--	--	--	2.51	1.97	0.87	.072	.500	7.6	67	—	--
"	6/18	2021	26.0	30	46	8	59	10	3.50	2.06	1.31	.005	.134	8.2	68	—	--
"	6/18	2306	25.5	--	--	--	--	--	3.95	2.12	3.47	.010	.079	6.3	81	--	--
"	7/29	0200	--	63	94	13	10	6	1.72	1.10	1.81	.038	.098	6.8	74	10	9
"	7/29	0800	—	195	258	23	20	15	3.99	1.19	2.65	.075	.169	4.7	72	13	13
"	7/29	1400	—	90	120	11	8	6	3.76	1.78	0.72	.070	.169	6.8	56	15	7
"	7/29	2000	--	41	65	5	22	18	1.76	0.66	0.78	.044	.119	7.0	66	8	4

CONTD.

HOLSTON ARMY AMMUNITION PLANT, AREA "B" KINGSPORT, TENNESSEE

Holston River

Station(1969)	Collected Date	Collected Time	Temp. °C	BOD ppm 2-da	BOD ppm 5-da	TOC ppm C	Susp. Solids ppm	Vol. Susp. Solids ppm	TKN ppm N	NH_3 ppm as N	NO_3-NO_2 ppm as N	O-PO_4 ppm P	Tot. asP ppm P	pH	Alk. ppm as $CaCO_3$	Chlor. ppm Cl	Turb. JC Units
Cooling Water 3a	6/18	0857	25.0	--	--	9	4	0	3.35	2.86	0.14	.103	.216	7.1	54	--	--
"	6/18	1050	26.2	--	--	--	--	--	2.85	2.48	0.21	.190	.298	7.7	49	--	--
"	6/18	1200	26.7	--	--	5	17	6	3.57	2.74	0.40	.100	.218	7.8	52	--	--
"	6/18	1401	26.8	--	--	--	--	--	3.52	2.77	0.20	.114	.234	7.8	48	--	--
"	6/18	1600	26.5	--	--	6	18	5	3.70	3.00	0.44	.167	.929	7.7	52	--	--
"	6/18	1805	21.0	--	--	--	--	--	1.86	1.70	1.00	.142	.228	8.0	60	--	--
"	6/18	2000	17.5	--	--	3	66	12	1.02	0.98	1.04	.058	.120	7.8	66	--	--
"	6/18	2005	17.0	--	--	--	--	--	1.15	0.98	1.00	.060	.111	7.7	67	--	--
Cooling Water 3b	6/18	0839	30.0	--	--	8	9	1	3.27	2.82	0.18	.102	.217	7.5	53	--	--
"	6/18	1025	30.5	--	--	--	--	--	2.80	2.38	0.27	.194	.300	7.7	48	--	--
"	6/18	1233	29.0	--	--	6	22	8	3.40	2.80	0.33	.096	.226	7.7	51	--	--
"	6/18	1425	29.5	--	--	--	--	--	2.98	2.32	0.43	.106	.226	7.8	61	--	--
"	6/18	1620	27.5	--	--	5	23	6	3.32	2.81	0.75	.140	.272	7.7	49	--	--
"	6/18	1808	23.0	--	--	--	--	--	1.53	1.40	0.95	.192	.335	7.9	75	--	--
"	6/18	2034	21.0	--	--	3	28	11	1.30	1.03	1.05	.068	.122	7.9	68	--	--
"	6/18	2211	20.0	--	--	--	--	--	1.21	0.99	1.03	.070	.142	7.7	73	--	--

NORTH FORK HOLSTON RIVER MILE 0.1

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
26	0400	50	25.0	7.8
26	0545	50	24.9	6.8
26	0815	50	24.3	7.2
26	0945	50	24.9	7.9
26	1100	50	25.5	8.5
26	1315	50	26.0	9.7
26	1455	50	27.0	10.5
26	1600	50	28.0	11.0
26	1703	50	28.0	11.4
26	1904	50	28.0	11.2
26	2000	50	28.0	10.6
26	2105	50	27.0	9.5
26	2200	50	27.5	8.7
26	2308	50	27.0	8.1
26	2400	50	27.0	7.8
27	0055	50	27.0	7.5
27	0154	50	26.0	7.1
27	0408	50	26.0	6.7
27	0630	50	25.5	6.2

SOUTH FORK HOLSTON RIVER MILE 5.6

DATE	TIME	HORZ. LOC.% LEFT BANK	TERMPERATURE °C	DO mg/1
July 1969				
25	2400	50	15.2	4.8
26	1020	50	15.8	4.7
26	1245	50	16.5	5.3
26	2230	50	15.0	4.7
SLUICE MILE 1.0				
26	0106	50	16.0	5.7
26	1215	50	22.0	6.5
27	0025	50	25.0	1.8

SOUTH FORK HOLSTON RIVER MILE 1.2

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	CO mg/l
July 1969				
26	0200	33	20.1	5.6
26	0705	67	20.3	5.7
26	0330	33	23.9	2.9
26	0330	67	24.6	3.4
26	0500	33	23.9	3.0
26	2500	--	24.2	3.5
26	2730	33	24.3	2.7
26	2730	67	25.0	2.9
26	0800	33	25.1	2.5
26	0800	67	26.1	2.7
26	0835	67	26.6	3.0
26	0915	33	25.7	2.7
26	0915	67	26.0	3.4
26	1000	33	23.9	3.1
26	1000	67	24.7	3.7
26	1115	33	25.3	3.7
26	1115	67	26.0	3.9
26	1200	33	27.0	3.5
26	1200	67	27.9	3.8
26	1400	33	26.8	4.6
26	1400	67	29.5	5.0
26	1505	67	29.0	4.7
26	1507	33	28.0	4.9

SOUTH FORK HOLSTON RIVER MILE 1.2

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE °C	DO mg/l
July 1969				
26	1610	67	30.0	3.9
26	1617	33	29.0	4.1
26	1710	67	30.0	3.3
26	1712	33	29.0	3.5
26	1805	67	29.0	3.8
26	1810	33	28.0	3.8
26	1914	67	29.0	3.3
26	1916	33	28.5	3.4
26	2008	67	30.0	2.7
26	2010	33	29.0	2.2
26	2113	67	29.0	2.4
26	2118	33	28.0	2.0
26	2208	67	27.0	2.7
26	2212	33	26.5	2.0
26	2316	67	27.5	2.4
26	2320	33	27.0	1.7
27	0008	67	28.0	1.8
27	0012	33	27.5	1.2
27	0103	67	28.0	2.0
27	2110	33	27.0	1.4
27	0205	67	26.0	2.0
27	0220	33	26.0	2.5
27	0330	33	26.2	1.5
27	0330	67	27.0	7.1

HOLSTON RIVER MILE 141.2

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
26	0615	33	20.2	2.5
26	0617	67	22.0	4.1
26	0710	33	22.0	2.0
26	0715	67	23.0	3.6
26	0240	33	23.1	1.1
26	0815	67	23.2	0.8
26	1200	33	26.0	1.2
26	1300	33	26.0	1.1
26	1300	67	26.0	2.0
26	1425	67	26.5	5.2
26	1425	33	26.5	1.3
26	1510	67	27.5	4.8
26	1510	33	27.5	1.9
26	1605	33	28.0	1.3
26	1605	67	28.0	3.2
26	1700	33	29.0	1.1
26	1700	67	29.0	1.9
26	1830	33	29.0	1.8
26	1830	67	28.1	3.0
26	1957	67	29.5	2.6
26	1957	33	29.5	1.0
26	2200	33	28.0	0.9

HOLSTON RIVER MILE 141.2

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
26	2200	67	28.0	1.4
26	2400	33	28.0	0.6
26	2400	67	27.7	1.8
27	0145	33	27.0	0.4
27	0145	67	26.5	1.3
27	0340	33	27.0	0.1
27	0340	67	27.0	1.0
27	0550	33	26.0	0.2
27	0550	67	26.2	1.6
27	0750	33	26.0	0.1
27	0750	67	26.1	1.4

HOLSTON RIVER MILE 137.9

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE	DO mg/1
July 1969				
26	1155	50	24.0	3.0
26	1215	25	25.0	3.2
26	1230	50	25.0	3.1
26	1235	75	30.0	3.7
26	1315	50	26.0	3.3
26	1355	50	--	3.9
26	1500	50	26.5	4.5
26	1800	50	28.0	3.4
26	1800	25	27.5	3.7
26	1800	50	28.0	2.8
26	1800	75	29.0	2.7
26	2015	50	28.0	2.0
26	2340	50	27.5	1.0
26	2350	25	--	--
26	2355	50	--	--
26	2400	75	--	--
27	0125	50	27.0	0.8
27	0325	50	27.0	0.6
27	0530	50	26.8	0.2
27	0530	33	27.0	0.4
27	0530	67	31.5	4.0
27	0730	50	26.5	0.3
27	0940	50	26.2	1.1

HOLSTON RIVER MILE 137.9

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE	DO mg/1
July 1969				
27	1130	50	27.0	1.6
27	1130	33	26.9	0.7
27	1130	67	31.5	1.9
27	1340	50	27.5	2.7

HOLSTON RIVER MILE 135.4

DATE	TIME	HORZ. LOC.% LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
26	1730	33	27.0	0.2
26	1730	67	26.5	6.2
26	1840	33	27.0	6.3
26	1840	67	27.0	6.2
26	2000	33	27.0	5.0
26	2000	67	27.0	4.8
26	2058	33	27.5	3.8
26	2100	67	27.5	3.3
26	2300	33	27.9	2.1
26	2300	67	27.9	1.2
27	0140	33	27.2	0.9
27	0143	67	27.2	0.8
27	0345	33	27.8	0.5
27	0350	67	27.8	0.8
27	0515	33	28.3	0.3
27	0520	67	28.3	0.3
27	0702	33	26.7	0.3
27	0705	67	26.7	0.4
27	0910	33	27.1	0.8
27	0910	67	27.0	0.6
27	1100	33	27.8	1.5
27	1100	67	27.8	1.5

HOLSTON RIVER MILE 135.4

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/l
27	1100	67	27.8	1.5
27	1300	33	28.5	3.1
27	1300	67	28.2	2.8
27	1530	25	29.0	5.3
27	1535	50	29.0	5.0
27	1540	75	29.0	4.7
27	1700	25	30.0	6.0
27	1705	50	30.0	5.5
27	1710	75	29.5	5.3
27	1705	25	29.5	5.2
27	1910	50	29.5	4.8
27	1915	75	29.5	4.5

HOLSTON RIVER MILE 131.5

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPRATURE °C	DO mg/1
July 1969				
26	2115	33	26.0	6.4
26	2115	75	25.0	5.7
26	2215	33	25.0	5.2
26	2215	75	26.0	4.1
26	2345	33	25.3	3.1
26	2345	75	26.0	3.1
27	0255	33	25.6	1.9
27	0300	75	26.7	0.9
27	0445	33	25.6	1.3
27	0450	75	26.7	0.8
27	0630	33	25.6	1.1
27	0635	75	26.1	0.6
27	0845	33	25.6	1.8
27	0850	75	26.7	1.0
27	1045	33	26.7	3.1
27	1050	75	26.7	2.7
27	1500	67	29.0	7.2
27	1505	33	29.0	8.5
27	1642	67	29.0	8.5
27	1645	33	29.0	9.7
27	1845	67	29.5	7.7
27	1850	33	29.5	8.6

HOLSTON RIVER MILE 131.5

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
27	2045	67	29.0	5.2
27	2050	33	29.0	6.2
27	2250	67	29.0	3.2
27	2255	33	29.0	4.3

HOLSTON RIVER MILE 128.3

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/l
July 1969				
27	0227	33	23.0	3.6
27	0233	67	23.0	4.6
27	0310	33	24.0	4.0
27	0325	67	24.0	4.0
27	0430	33	29.0	3.5
27	0435	67	24.0	3.6
27	0745	33	25.6	0.9
27	0750	67	24.4	1.3
27	0925	33	26.1	1.1
27	0930	67	25.6	1.9
27	1125	33	26.7	3.0
27	1130	67	26.1	3.6
27	1330	33	26.7	4.8
27	1335	67	26.7	5.2
27	1530	33	28.5	7.1
27	1530	67	28.5	6.4
27	1730	33	29.2	8.1
27	1730	67	29.2	7.6
27	1930	33	29.0	8.2
27	1930	67	29.0	7.4
27	2145	67	28.5	6.3
27	2150	33	28.5	7.1

HOLSTON RIVER MILE 128.3

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
27	2330	33	28.5	6.3
27	2335	67	28.5	5.0
28	0130	67	28.5	4.0
28	0135	33	28.0	5.0
28	0345	33	28.3	2.7
28	0345	67	28.0	2.5

HOLSTON RIVER MILE 125.30

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
27	0815	33	23.5	4.1
27	0815	67	24.0	4.2
27	0945	33	24.5	4.1
27	0945	67	24.5	4.1
27	1115	33	25.0	3.9
27	1115	67	25.0	4.4
27	1255	33	26.7	5.4
27	1300	67	25.6	6.5
27	1435	33	26.7	6.6
27	1440	67	26.7	8.8
27	1605	33	27.5	7.8
27	1610	67	27.5	7.9
27	1815	33	27.5	7.6
27	1815	67	27.5	8.9
27	2015	33	28.2	7.5
27	2015	67	28.2	7.5
27	2220	33	28.0	7.1
27	2220	67	28.0	6.5
28	0025	67	28.0	5.8
28	0025	33	29.0	6.3
28	0330	33	28.0	4.9
28	0330	67	28.0	4.1
28	0430	33	28.0	4.5
27	0430	67	27.5	3.8
27	0630	33	28.0	3.7
27	0630	67	27.5	3.3
27	0830	33	28.0	3.3
27	0830	67	27.6	3.2
27	1030	33	28.2	4.0
27	1030	67	28.0	4.2

HOLSTON RIVER MILE 118.4

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
27	2015	33	26.0	10.3
27	2015	67	26.0	11.7
27	2230	33	26.0	7.1
27	2230	67	26.5	7.4
27	2330	33	26.0	6.7
27	2330	27	25.5	7.1
28	0100	33	25.5	5.5
28	0100	67	25.5	5.7
28	0400	33	25.0	4.1
28	0403	67	25.0	3.9
28	0600	50	26.5	3.6
28	0800	50	27.0	3.3
28	1000	50	27.0	4.1
28	1201	50	28.0	7.1
28	1400	50	28.5	8.5
28	1600	33	30.0	11.1
28	1605	67	29.5	10.7
28	1755	33	30.0	10.7
28	1800	67	30.0	11.1
28	2000	33	30.0	9.5
28	2005	67	30.0	10.5
28	2200	33	29.0	7.5
28	2205	67	29.0	7.8
28	2400	33	29.0	5.6
28	2402	67	29.0	5.6

HOLSTON RIVER MILE 115.87

DATE	TIME	HORZ. LOC. % LEFT BANK	TEMPERATURE °C	DO mg/1
July 1969				
28	0615	50	25.0	4.4
28	0815	50	25.0	3.6
28	1115	50	27.0	3.7
28	1315	50	27.5	5.4
28	1515	50	28.7	7.6
28	1715	50	29.0	9.9
28	1920	50	29.5	10.6
28	2115	50	30.0	9.6
28	2315	50	30.0	8.7
29	0115	50	29.0	7.0

APPENDIX I

LIST OF PARTICIPANTS

Holston River Study 1969

Thomas Gallagher -- Chief, Engineering Services (EPA)

Paul Wagoner -- Sanitary Engineer (EPA)

Roy Whatley -- Hydrologist (EPA)

Dennis Cafaro -- Sanitary Engineer (EPA)

Robert Schneider -- Biologist (EPA)

Thomas Bennett -- Chemist (EPA)

Ronald Weldon -- Biological Technician (EPA)

Raymond Wilkerson -- Engineering Technician (EPA)

Thomas Sack -- Chemical Technician (EPA)

Wilburn Holsomback -- Engineering Technician (EPA)

Roy Weimert -- Engineering Technician (EPA)

Greer Tidwell -- Chief, Special Projects (TVA)

James Ruane -- Sanitary Engineer (TVA)

Allan Smalley -- Sanitary Engineer (TVA)

Samuel Geer -- Engineering Technician (TVA)

Robert Hunt -- Regional Engineer (Tennessee Department of Water Pollution Control)

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